THE USE OF A FEEDBACK SYSTEM INCORPORATED WITH A MORPHOLOGICAL MATRIX FOR PRODUCT/SYSTEM DEVELOPMENT.

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THE USE OF A FEEDBACK SYSTEM INCORPORATED WITH A MORPHOLOGICAL MATRIX FOR PRODUCT/SYSTEM DEVELOPMENT.

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ABBREVIATIONS AND NORMENCLATURE

DI – Designer's Input

Data – is the collection of raw quantitative or qualitative facts, figures, input, materials, measurements, statistics, scores, etcetera. The organization of this data becomes information.

ECN – Engineering change notice, a request to change a portion of the design or functionality.

ICT – Information Communication Technology

ID – Industrial Design

Industrial Design – Industrial design (ID) is the professional service of creating and developing concepts and specifications that optimize the function, value and appearance of products and systems for the mutual benefit of both user and manufacturer. [www.idsa.org, 2006]

Information – Is the organization of data in such a way that becomes useful to a specific need.

Feedback – The flow of information from once design phase to another. Typically from a more advance stage to an earlier stage.

Feed-forward – Similar to feedback information but with the implication that the information flows from an earlier stage to a much more advanced stage. Pehaps skipping intermediate steps in the process.

Parameter – The portion of a morphological matrix that describes a key feature of a design that is being addressed with design concepts, or Parameter Options. Shows what a design should have or be. The Parameters are numbered so that references can be made to specific Parameters.

Parameter Number – The number referencing a specific Parameter. Often these numbers may be referenced by the researchers input column or the designer's input column.

Parameter Option – or Parameter Component is a single concept for a Parameter. Multiple Parameter Options are typically developed for each Parameter.

RI – Researcher's Input

Semiotics – The theory and study of signs and symbols, especially as elements of language or other systems of communication, and comprising semantics, syntactics, and pragmatics. [The American Heritage Dictionary of the English Language, 2000]

SUMMARY

Critical steps in the design process is the gathering of data, processing the data into a useful form of information (a design concept) which meets specific needs, passing this refined design solution down the path to production, where it is released into the larger environment. Within the designing process there are multiple feedback loops as the solution becomes more refined. Even as it reaches the final end user, other design refinement feedback loops continue as new and improved products or systems are developed. Along with the interdisciplinary teams involved with the product/system development, the more complex the product or system the more critical the organization of the data. This paper will present and test a concept of a design feedback and feed forward communication tool for product/system design that uses Dr. Walter A. Schaer's Three Functions of an Artifact as the methodological structure for design development.

The essence of this design tool is the merging of a new communication system within an existing methodology of organizing complex systems into a morphological matrix, developed by Dr. Walter A. Schaer, based on the Charles Morris's work on semiotics. This communication tool is a new feedback / feed forward mechanism which correspond with the semiotic structure in a morphological matrix to assist the designer develop design solutions. The research will measure the success rate of the tool in the design process, examine of how the designers took advantage of the new tool, and evaluate their perception of its usefulness.

CHAPTER 1

INTRODUCTION

During the step in developing a system or product design solution, a key component is the communication. Often researchers communicate their information in forms of data, charts, tables, etcetera to the designers. The designers communicate their ideas in forms of sketches, graphics, models, digital cad files, etcetera to the engineers. The engineers communicate their input in more two or three dimension representations and other specifications to the manufactures. The manufactures takes a version of the original Industrial Designer's ideas and communicates this to the public in the mass produced artifact. This process is not as linear as it sounds. Feedback and feed-forward occurs repeatedly in this process to obtain the ideal solution. With today's current information communication technology, the flow of this communication is increasingly easy between departments and around the world. Not only is the delivery of information a key factor to the product development process, but so is the order, structure, and form of this delivered information. Even through designers may perform many of the duties of researcher, engineer, and etcetera, the communication of information remains just as critical.

Steps in the design process with information feedback.

The process for both problem identifying and problem solving does not involve an unexpected enlightenment or serendipity while one is walking down the street. Typically the process occurs in a similar sequence of steps executed by a wide variety of disciplines such as material sciences, technology, design, humanities, and the fine/performing arts. Figure 1 shows the problems solving process "the four stages of Preparation, Incubation, Illumination, and Verification of the final result can generally be distinguished from each other" [Wallas, 1926].

Any time during these phases there are opportunities for feedback to an earlier stage to review, gather more information, change parameters, adjust methodology, or change problem statement. Another description by Pahl and Beitz regarding a feedback effect in a technical system can also be applied to the steps and activities of a systematic product design methodology. They suggest that the designer in the development system is not working in isolation but is part of a superior system, made up by the product development team. This product development system is composed of a multitude of various "input providing" members like researchers, designers, engineers, marketers, manufactures, etc. An effective product development system will have various forms of feedback mechanisms that lead to further actions [2 Pahl & Beitz, 1996]. A good feedback system can function as a self organizing system. It is critical to provide the needed information to the system, from various points of the system, so that the system can react and can perform effectively.

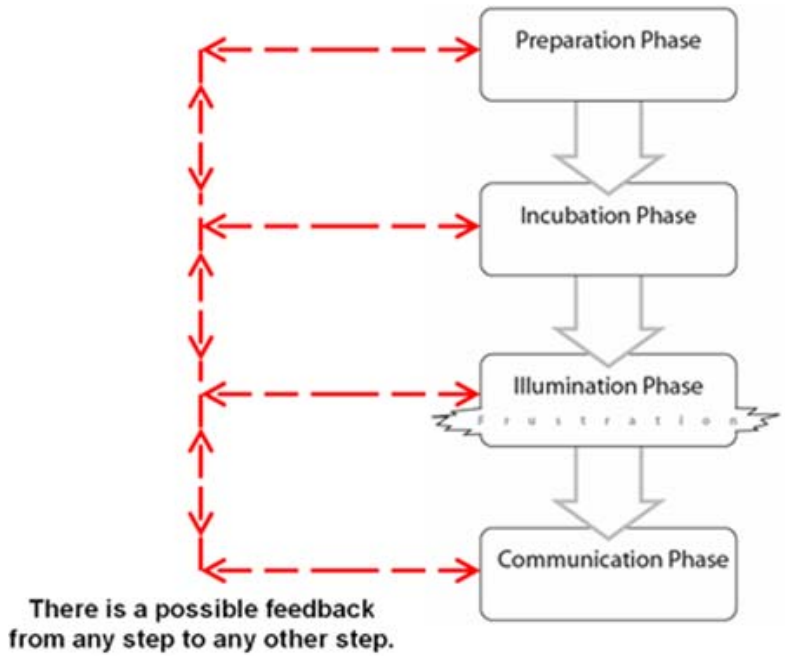


Figure 1: Wallas's steps of problem solving with feedback.

Preparation Phase

During the Preparation phase a goal is defined on which to apply the designer's problem solving efforts. The designer's efforts begin with an understanding of the problem and goal through "the whole process of intellectual education" [Wallas, 1926]. "Our mind is not likely to give us a clear answer to any particular problem unless we set it a clear question, and we are more likely to notice the significance of any new piece of evidence, or new association of ideas, if we have formed a definite conception of a case to be proved or disproved" [Wallas. 1926]. The "intellectual education" Wallas refers to is the gathering of data and information in its various forms that is relevant to the target goal. Through out this portion of the paper "data" will be referring to the following definition:

> "Is the collection of raw quantitative or qualitative facts, figures, input, materials, measurements, statistics, scores, etcetera. The organization of this data becomes information. Data on its own has no meaning, only when interpreted by some kind of data processing system does it take on meaning and become information. For example, "1234567.89" is data. "You have $1,234,567.89 in your bank account" is information. Information is an organized grouping of data that has meaning relative to a particular subject. The data must go through a data processing machine (such as a skilled researcher and/or designer) before it becomes meaningful information relative to a particular subject matter". [Howe, 2005]

Often various disciples may be involved in the research and design process. With the interdisciplinary backgrounds of the research/design group comes a wide variety of formats of information:

> "Psychologists, for example, engage in practices that are steeped in academic rigor. For a psychologist, the design process will invariably begin with a literature review of books and articles published in peer-reviewed journals. The ultimate deliverable for a design project will often be an extensive written document describing the design in detail for the client. Psychologist will submit white papers describing the design process and outcome for publication as a matter of course too.
>
> Like psychologists, designers will generally perform a literature review. Similarly, designers will compare and contrast existing, competing products and will perform a cursory task analysis… Similarly, designers will compare and contrast existing, competing products and will perform cursory task analysis. Scenario writing will also be employed by the designer although designers are prone to editorializing the scenarios in an attempt to establish ethnographic context for the design rather than simply generating stories of purely factual usage. Designers use scenarios to immerse themselves in the design and to understand the intended user." [Berryman 2002]

The information formed from various perspectives provides a higher quality set of information. The more specific the data going into the design process will result in a more accurate output design solution. "Chance only favours intervention for minds which are prepared for discoveries by patient study and persevering efforts" [Koestler, 1964]. This gathered information typically is used to understand the problem, environmental context, and the user's needs. Even at this early stage of the problem solving process the designer can feedback to review existing documented solutions of other design projects with similar problems.

Incubation Phase

Once the information has been gathered, the designer begins to evaluate the larger problem space. The Incubation step begins when the information has been consumed by the

designer, which is the data processing machine. The designer's basic goal is developing a solution which meets the needs of the end users, the engineers, toolmakers, manufacturing, marketing, finance, sales, and etcetera with in a given time frame. The efforts of the designer to assemble all of the complex and sometimes conflicting needs into a solution will push the designer to points of frustration.

One existing structure can be used to organize these stakeholders' needs into three different functions; human function, production function, and technical function. This methodological means to organize these elements will be introduced later in this paper.

Based on design student's anecdotal experience with the design process, there are three reasons that the designer may not go through frustration. First, it is due to the goal being to easy, which may result in a solution lacking in innovation. The second possibility is that the goal is being set is too far way from the capabilities of the designer and possibilities for good solutions are nearly unattainable. A third way, of a designer to avoid the frustration, is if they develop one single solution and refuse to look into other options or concepts. If the designer is not going through frustration there may be something wrong. Signs of frustration were made apparent in participants during the pre-testing of the research data gathering tool developed for this paper. When no solution was reached by the participants, or the participants gave up too early, changes were made in the research tool.

While the designer is in the Incubation phase, which includes the occasional periods of frustration, both the unconscious and the conscious mental activities are occurring. During this time there are many feedbacks loops to the Preparation phase's information. This feedback may often be requests to find or create needed information, or to possibly readjust the target goal. Hopefully at some point, resulting in an illumination or "ah-ha" experience.

Illumination Phase

The illuminated new concept solution is a consequence of the Preparation, Incubation (with frustration) experience. An example of the Illumination or the "ah-ha" experience was

given by Helmholtz, a famous German physicist. After he was involved with a great deal of Preparation and was going through the Incubation phase that “in all directions… happy ideas came unexpectedly without effort, like an inspiration. So far as I am concerned, they have never come to me when my mind was fatigued, or when I was at my working table… They came particularly readily during the slow ascent of the wooded hills on a sunny day.” [Rignano, 1923] The new concepts are simply plans of products. The Incubation, Frustration, and Illumination phases the designer goes through results in the formation of the product or system solutions.

Communication Phase

The Industrial Designer differs from the crafts person or artist who is dealing with the final artifact [Schaer, 1963]. The Industrial Designer is working with in a dynamic plan or concept of something to be produced and used. In the Communication phase the Industrial Designer’s best solution concepts or plans are documented. This concept documentation may come in forms of written specification, drawings, physical models, and/or digital models. Once documented and a concept is selected it is then communicated forward to the manufactures. The manufactures may have already feedback to the designer what capabilities they had during the problem solving Preparation phase. When the solution concept requires changes to comply with the manufacture’s capabilities and those changes affect the designer, the concept solution is feedback to the designer with the engineering change notices (ECNs) The designer then must make these changes and try to maintain the design integrity while meeting the manufacture’s needs. Then the manufacturers bring the concept to reality, sometimes in the thousands or millions. The realized concept solution is then communicated in the manufactured form, or semiotic “sign vehicle”, to the consumer/user. Even from this point there is feedback to the designers through marketing research channels. From this feedback revisions are made, new targets are set for the next iteration of the artifact to be released in the market. This is a good example of how there is no final design solutions but simply solutions that, due to time

constraints, are released in to the market while the development continues based on the continuous feedback steps [Schaer, 1963].

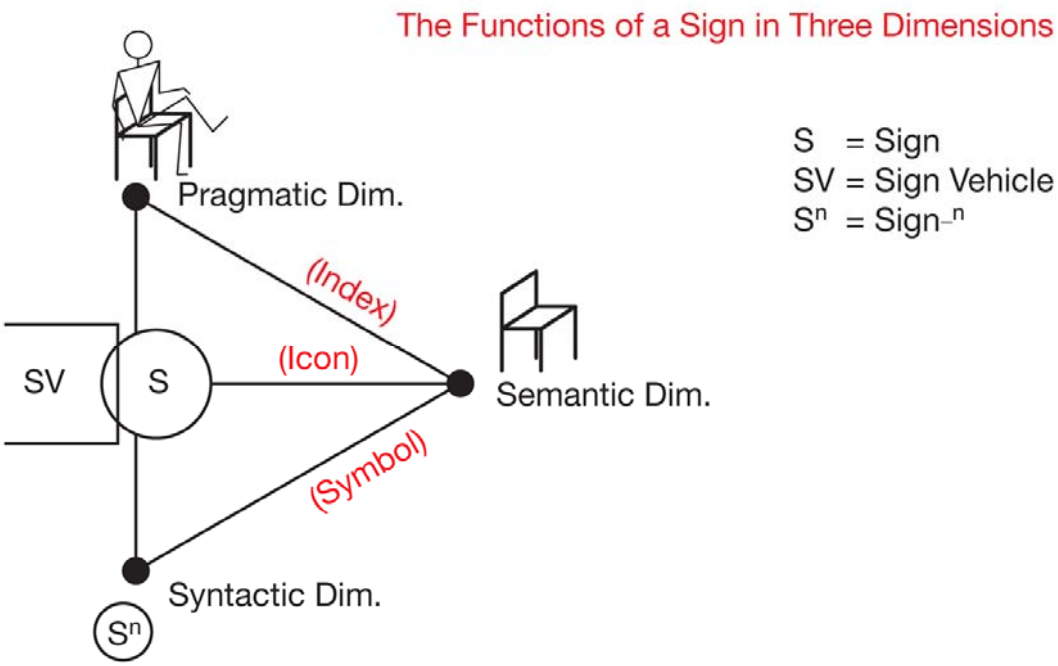


Figure 2: Functions of a Sign in Three Dimensions [Schaer, 1963]

Semiotics and the Theory of Sign.

"Semiotics holds a unique place among the sciences. It may be possible to say that every empirical science is engaged in finding data which can serve as reliable signs; it is certainly true that every science must embody its results in linguistic signs." "Semiotics is not merely a science among sciences but an organon or instrument of all the sciences." [Morris, 1938] In other words, the language of a field of work or study such as mathematics, chemistry, and even poetry all use signs. The Theory of Sign addresses how "the process in which something functions as a sign may be called semiotics."[Morris, 1938] According to The American Heritage Dictionary of the English Language, the definition of semiotics is:

"the theory and study of signs and symbols, especially as elements of language or other systems of communication, and compromising semantics, syntactics, and pragmatics".[American Heritage Dictionary, 2000]

The sign interacts and relates with the environment, user and itself (see Figure 2). Table 1 presents the three dimensions in the theory of signs as the pragmatic, semantic, and syntactic.

Table 1: Descriptions of pragmatic, semantic, syntactic dimensions of the Theory of Signs.

Pragmatic	**Semantic**	**Syntactic**
-"the relations of signs to their users (interpreters)". [Schaer, 1963] - "A sign can give information about an object". [Schaer, 1963] - "all signs have a directedness toward objects, or at least purport to be about somethings". [Liszka, 1996] - "To the man and/or society" [Schaer, 1963]	- "The relations between signs and things signified (designata)". [Schaer, 1963] - "it can inform about a form-condition of something" [Schaer, 1963] - "represent something to some sign user, i.e., something which represents the representation as a representation." [Liszka, 1996] - "To the total planning and production process" [Schaer, 1963]	- "The relationship between signs" [Schaer, 1963] - "information about an existence" [Schaer, 1963] - "must represent or correlate with that object in some respect in some respect or capacity" [Liszka, 1996] - "To its parts, itself, and other physical objects and environment". [Schaer, 1963]

The pragmatic dimension deals with the relation of the sign and its use. The index function between the pragmatic and the semantic dimensions is a pointer or director of the sign. The semantic dimension deals with its meaning. The iconic function involves graphic representation of something within the sign. Syntactic dimensions are the technical aspect of the

sign. It is concerned with the grammatic or order of the sign. The symbolic function between syntactic and semantic dimensions are the symbols used to communicate. For example, letters in a sentence, not pictures. These symbols must be learned. All of these dimensions and functions must have a mediator or the thing that conveys the message. This mediator is called the sign vehicle. For example, the billboard is the sign vehicle of a road side communication device. Another example would be the shoe which is the vehicle for the foot protection device. The All signs must have one to exist.

The sign can not be considered independent from its environment. The sign is a part of a much larger situation, whole, or complex system. The syntactic dimension is part of the connections the sign to this larger system. According to Dr. Walter Schaer, who uses the Theory of Signs to develop his Three Functions of an Artifact structure for Industrial Design:

"The various dimensions of a sign are, of course, only different aspects of the same event or object in a unitary process and they are, therefore, interrelated and overlap one another; thus, they cannot be completely isolated. Also, the three levels of semiotics must be understood as successive abstractions from pragmatic-semiotic and syntactics." [Schaer, 1963]

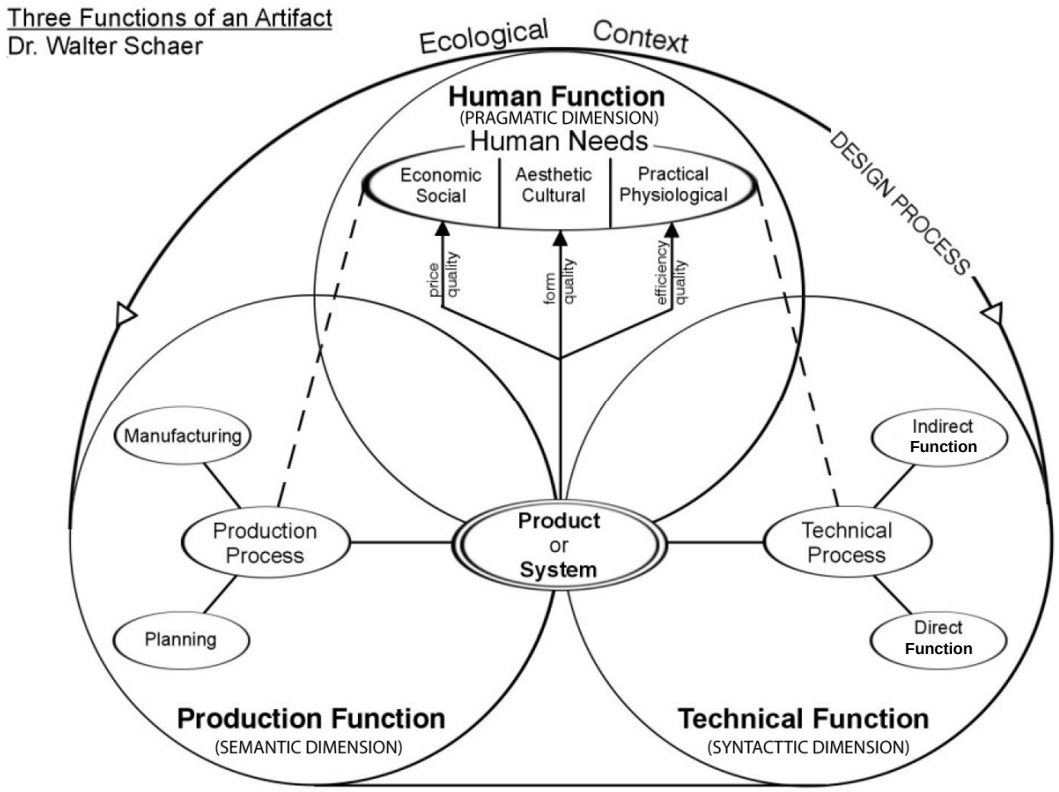


Figure 3: Three Functions of an Artifact [Schaer, 1963]

Three Functions of an Artifact, incorporating semiotics in Industrial Design.

Charles Morris's Theory of Signs was based on a linguist's point of view. Dr. Schaer's work in the Three Functions of an artifact transformed the Theory of Signs into a theory of design, as seen in Figure 2. The pragmatics, semantics, and syntactics are the three functional dimensions of an artifact: Human Function, Production Function, and Technical Function. [Schaer, 1978] The Three Functions of an Artifact, shown in Figure 3, should be used as a map for designers to keep the whole design process in proper perspective. Descriptions of each of these functions will be provided along with charts that will illustrate the complex segments of the designer considerations and process.

Because a sign is not independent of its environment and must relate to other elements outside of it, the ecological context encircles the three dimensions. The whole design process also encircles the three dimensions because the structure of the Three Functions of an Artifact also covers all of the steps the problem field, or product development path. This tool is also purposeful for the communication between all the various members of the development team. Charles Morris concluded that "Semiotics provides a basis for understanding the main forms of human activity and their interrelationship, since all these activities and relations are reflected in the signs which mediate the activities."[Morris 1938] Each of these dimensions includes different functions of design.

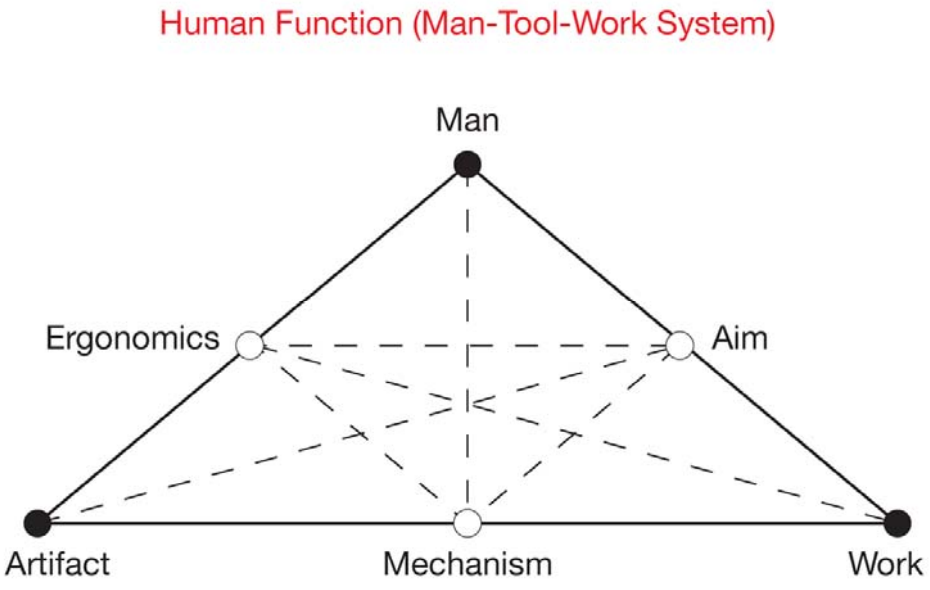


Figure 4: Considerations regarding Human Function (Man-Tool-Work System) [Schaer, 1963]

In the pragmatic dimensions the human functions includes the needs of the user and the society and the direct connection the artifact or system has with them. These human factors are

economic, social; cultural, aesthetic; practical, physiological needs. The economic and social needs involve the price quality which includes the social costs. The aesthetic and cultural needs involved the form quality, which includes the operational object language. The practical and physiological needs involve the efficiency quality. Efficiency qualities may include anthropometrics, Universal Design issues, safety, and the environmental impact. Figure 4 presents other elements that the designer may take into consideration for the user's encounter with the artifact. The emotional, spiritual, and material conditions of the human needs can appear in all three groups of the human demands. [Schaer 1963] The design process starts with the human needs.

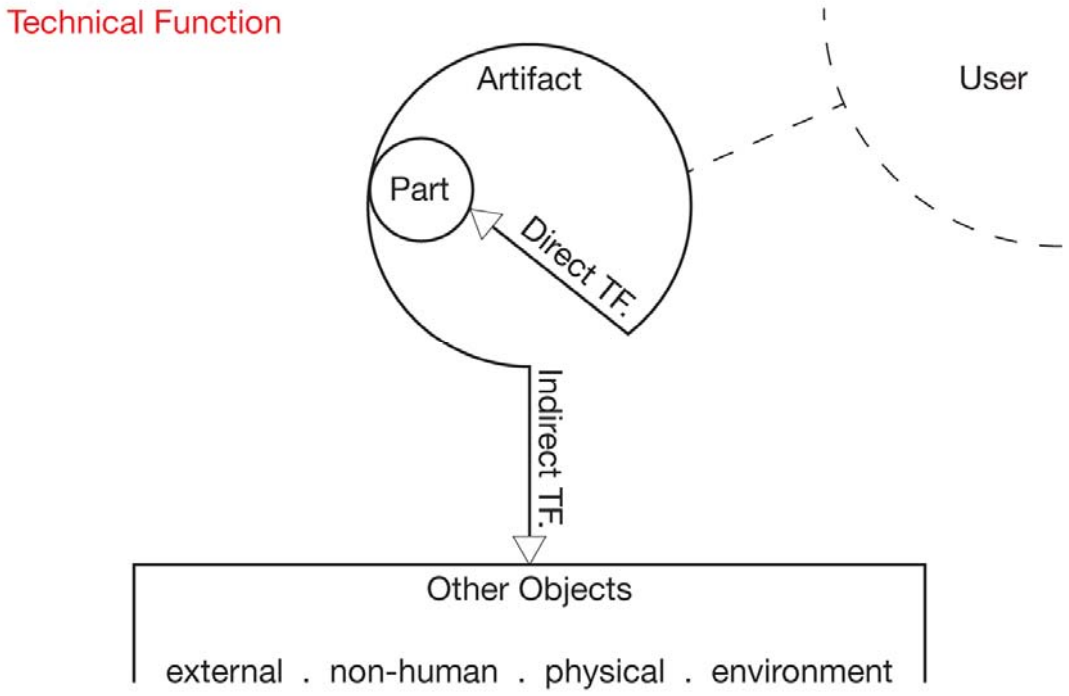


Figure 5: Technical Functions example [Schaer, 1963]

The technical function, demonstrated in Figure 5, is concerned with the technical process, both direct and indirect technical functions. The direct technical function is how one part of an artifact interacts with another part of the artifact or the relationship of the parts of the object is to the whole. For example, how a screw is involved with holding the two pieces of wood together. The indirect technical function is how part of an artifact interacts with its non-human environment; such as sitting device's foot interacts with a carpet, wooden, or tile floor it rests on.

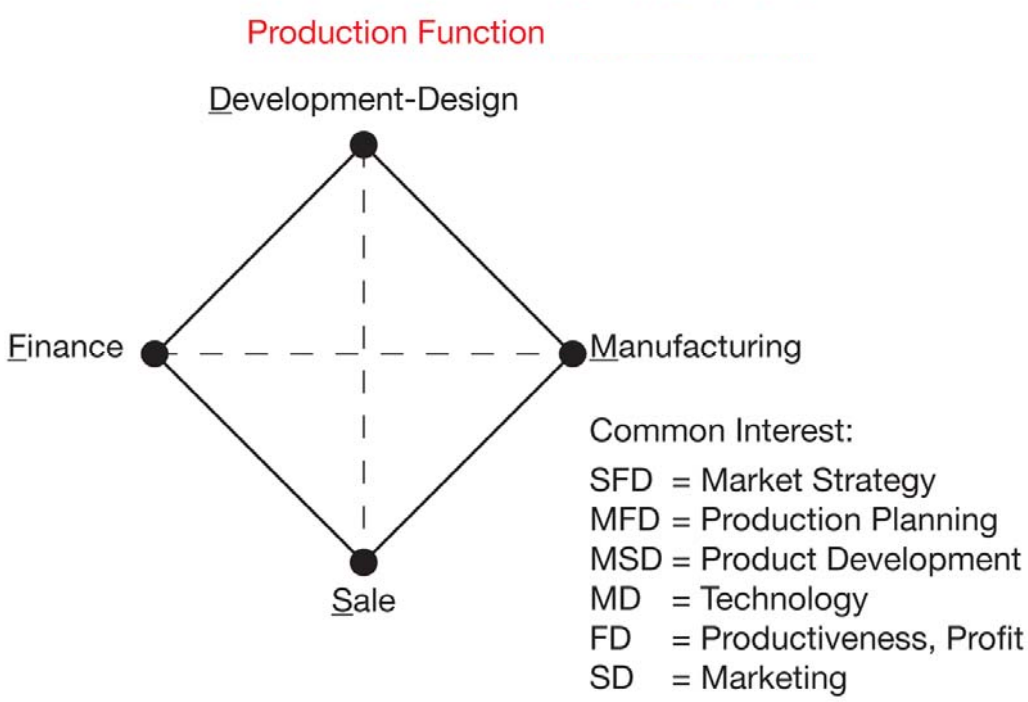


Figure 6: Interests found in the Production Function [Schaer, 1963]

The Industrial Designer's focus is also in tune with the production function of the semantic dimensions which is concern with production process. The production process is

involved in the planning, genesis and manufacturing, materialization of the artifact [Schaer 1978]. The semantics or meanings of the product development is different than that of the artesian or crafts person who makes the goal object. The development team develops the plans in various forms such as drawings, calculations, models, and statistics. This information is then passed to the manufacture to produce the actual realized product.[Schaer, 1963] Several elements of the product development team are represented here and are shown in Figure 6. These stakeholders include the design and development team, manufacturing, sales, and finance. These members combined interests tend to fall under market strategy, production planning, product development, technology, productiveness, profit, and marketing. These elements of the Production Function are thus divided into the Planning and Manufacturing.

The combination of the pragmatic, syntactic, and semantics view (Human Function, Production Function, Technical Function) of an artifact or a system provides a structure to discuss any and all products or systems, just as semantics can function for the description of any language. All of the basic components of a language are represented no matter what kind or the level of complexity of a language. With this universal structure, charts and other organizational formats may be outlined based on this Three Functions of an Artifact. Doing so will reduce the possibility for designers to work with a too narrowed point of view. This will enable to designer to consider the entire system when problem solving.

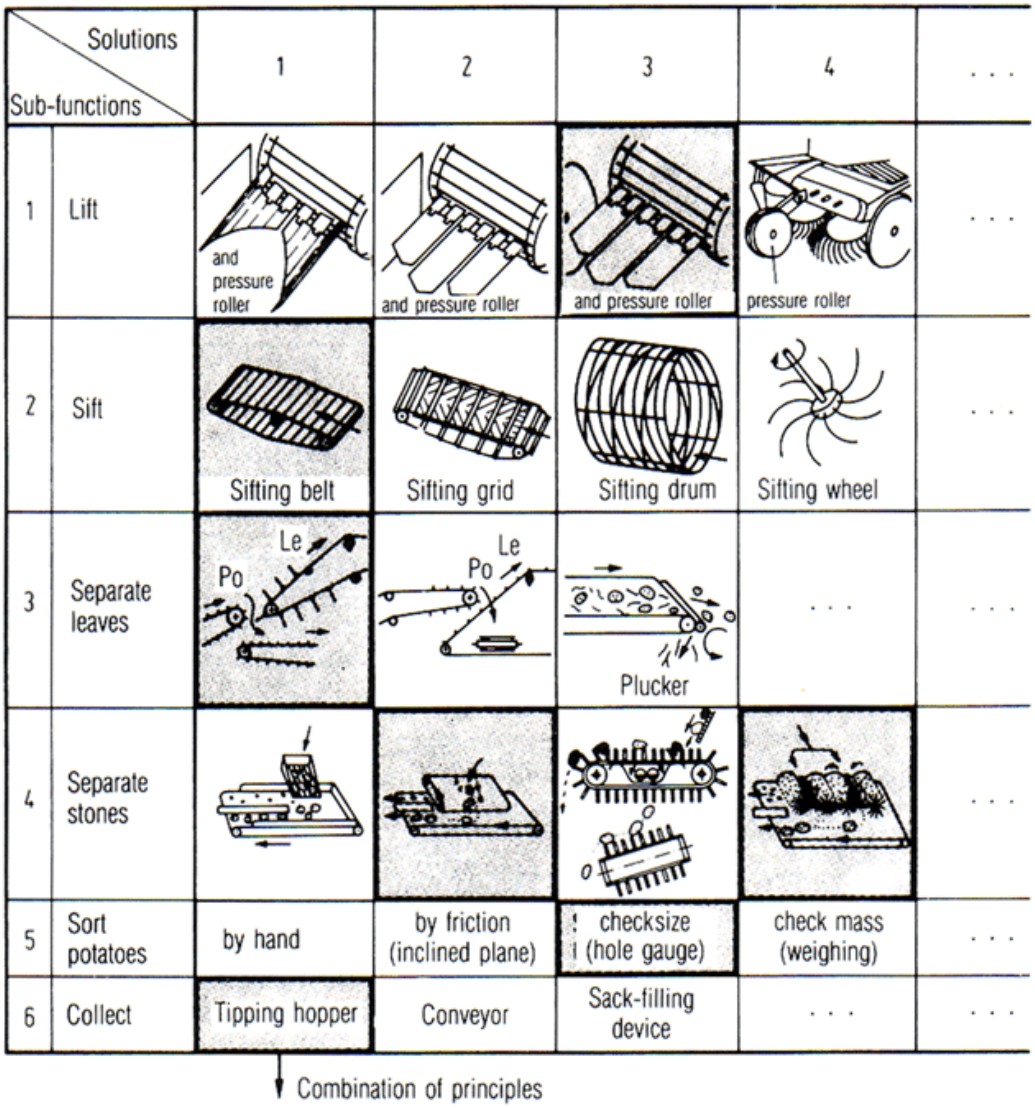


Figure 7: Example of engineering morphological matrix for a potato harvesting machine [Pahl, Beitz, 1996]

Use of a morphological matrix in decision making.

The morphological matrix is a methodology to organize numerous possible solutions for particular parameters of a system. Each of the parameters that represent the entire system can have a single listed solution selected. The combination of each parameter solution would comprise the overall system solution and several separate system solutions can be represented in each matrix. There are two key strategies in the use of this methodology: a) “Dividing the design

task into smaller tasks, as it reduces the cognitive effort required from the designers and thereby increases their innovative capacities, and b) generate several conceptual solutions thereby increasing the probability of identifying an innovative solution". [Weber, Condoor, 1998]

The use of the morphological matrix is not a creative solution machine, it does not replace creative thinking, and the selection of solutions requires the interpretation of the designer. According to Weber and Condoor, "it allows the designer to consciously explore design alternatives with out confining them to the human short-term memory limitations". [Weber, Condoor, 1998] However, it does provide a methodology to organize and document design alternatives. These design documents can be used as the design record. The information which decisions were made on, the specific research requests are also documented. This type of information can be useful for the development of solutions when it is incorporated in a morphological matrix but also beneficial for evaluation tools such as analysis and evaluation checklists, right-wrong charts, and competitive product charts. All of these charts can be broken down and organized using the Three Functions of an Artifact

How to fill out the chart

The morphological matrix is constructed with a grid of columns and rows. The first column provides a space to list the functions of parameters. In the adjacent rows, each function/parameter is listed by possible solutions that will achieve the function or meet the parameter, as shown in Figure 7. To fill in the possible solutions the designer may use images, sketches, or text to describe each solution. Once the chart has been filled in the designer must go through and select the ideal solution for each function/parameter to create the effective conceptual design [Weber, Condoor, 1998]. One issue is the possibility to generate every variation feasible. "It has been found best at this stage to reject solutions that represent

unimportant variants, and to realistically restrict the solution field according to the boundary conditions, and the nature of the assigned problem". [Hubka, 1982]

The Incorporation of Three Functions of an Artifact as an outline

Since 1960, the morphological chart has been used by industrial designers with the Three Functions of an Artifact as the outline. This three page chart, found in Figure 8, will allow industrial designer to cover every design element with many different possible solutions.

The chart makes it easy to visualize the different possible solutions. Other than new design concepts, it can also be used to show "current solutions", as well the "ideal solution". The morphological matrix can be utilized in developing other possible solutions to other similar problems. It also can be offered as proof in legal situations [Ullman, 2003].

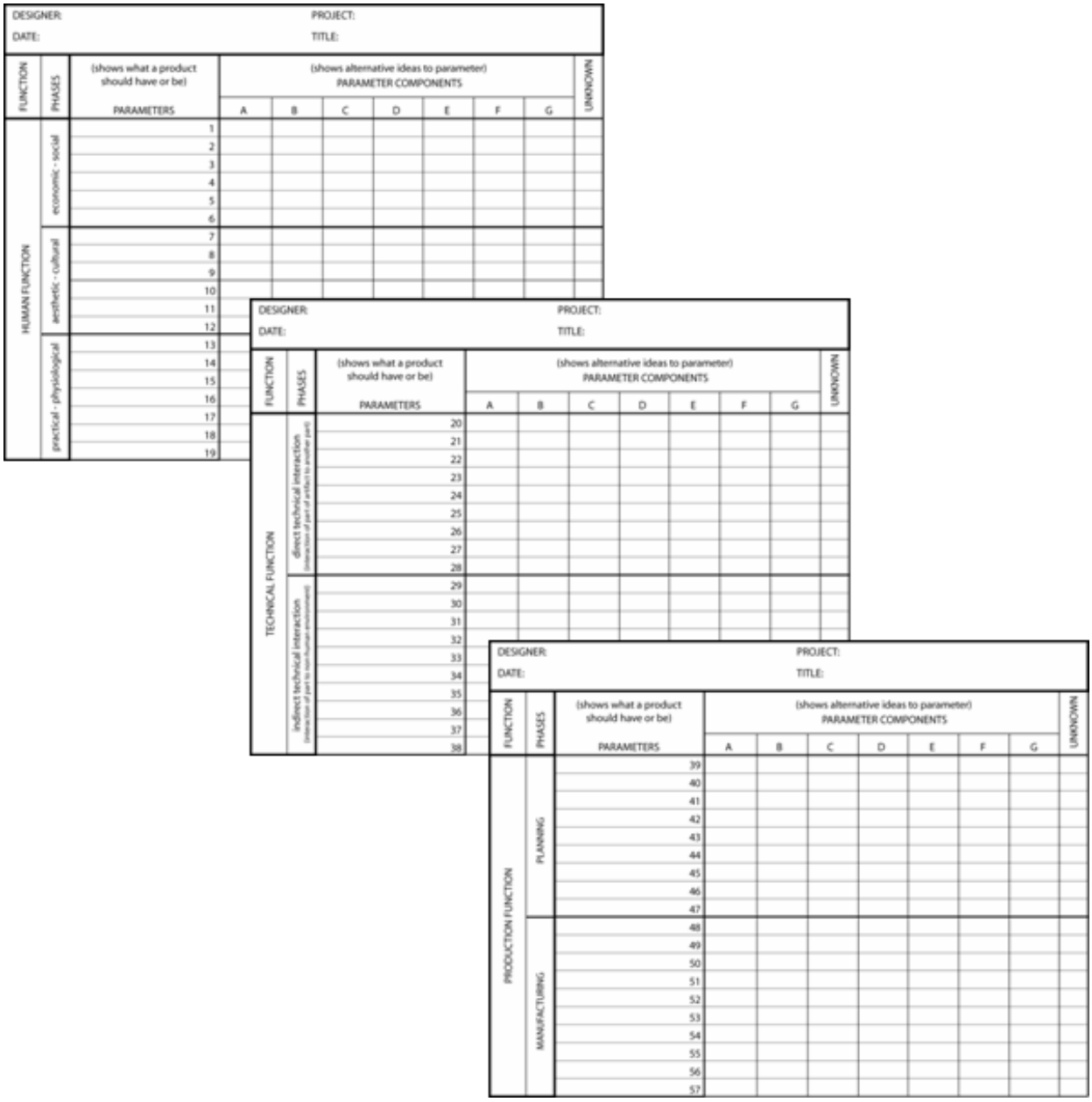


Figure 8: Morphological matrix layout using Three Functions of an Artifact.

As a tool, within a complex problem space, the matrix can be used to make logical investigation of every aspect of the design problem. The Parameters are assigned to a column where seven slots are open for Parameter possibilities. The designer should record as many solutions for each Parameter Options (Component) as possible. It can be recorded as written or

illustrated form. Not all Parameters can be controlled by the designer. Some are controlled by the manufacturers, consumers or even nature. Since some of these Parameters can not be controlled by the designer it should be noted in the “unknown” column at the end of the Parameter Component column.

After the matrix is filled out, it can be used to build complete theoretical solutions. By drawing lines from one Parameter box to another current solutions and idealistic solutions can be shown and compared with other new realistic solutions. One important rule is to use only one box in each Parameter component for each solution. There should only be three to six realistic solutions per chart to reduce confusion.

The morphological matrix is broken down and outlined into the Three Functions of an Artifact as shown in Figure 9.

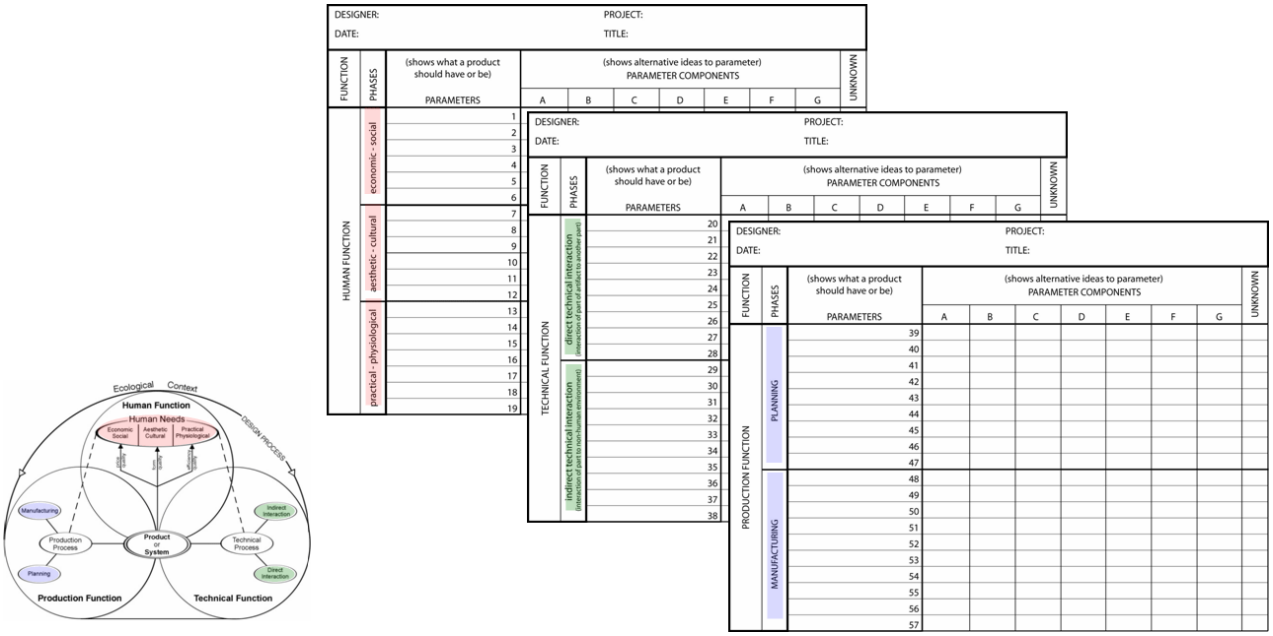
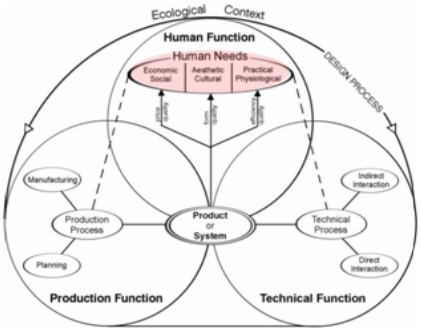


Figure 9: Human Function, Technical function, and Production Function outlining the matrix.

The Human Function portion of the matrix is subdivide into three sections; 1. the Economic – Social, 2. Aesthetic – Cultural, and 3. Practical – Physiological, as seen in Figure 10. The Technical Function portion is divided into two sections; the Direct Technical Function and the Indirect Technical Function, as shown in Figure 11. The Production Function portion of the matrix is divided into two sections; Planning and Manufacturing, presented in Figure 12.

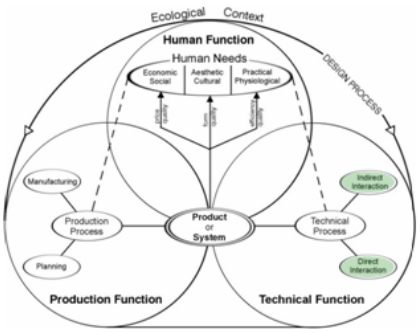
Once the charts have been filled out the designer can develop system concepts by selecting one Parameter Component for each Parameter which is done throughout the entire chart to develop the entire system concept. Multiple solutions can then be combined in a single chart. This is demonstrated in Figure 13 and Figure 14.



DESIGNER: PROJECT:
DATE: TITLE:

FUNCTION	PHASES	(shows what a product should have or be) PARAMETERS		(shows alternative ideas to parameter) PARAMETER COMPONENTS A	B	C	D	E	F	G	UNKNOWN
HUMAN FUNCTION	economic - social	Cost	1	Free	$2.44	$5.00	$7.25				
			2								
			3								
			4								
			5								
			6								
	aesthetic - cultural	Color	7								
		Extruded grip profile	8								
			9								
			10								
			11								
			12								
	practical - physiological	Blade safety method	13	none	cap	retracted					
		Ergonomic Grip finish	14	soft	tacky	rough	smooth				
			15								
			16								
			17								
			18								
			19								

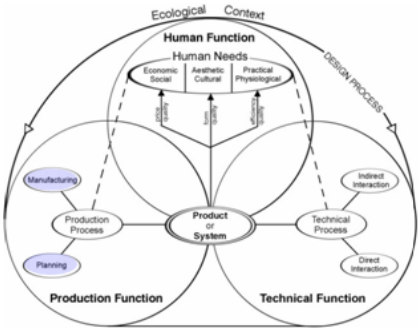
Figure 10: Filling in Parameters and Parameter Components in the Human Function.



DESIGNER: PROJECT: **Design of a X-acto knife.**
DATE: TITLE:

FUNCTION	PHASES	PARAMETERS		(shows alternative ideas to parameter) PARAMETER COMPONENTS A	B	C	D	E	F	G	UNKNOWN
TECHNICAL FUNCTION	direct technical interaction (interaction of part of artifact to another part)	Blade locking method	20	Friction fit	adhesive	pinch	magnet				
		Number of moving parts	21	2	3	4	5	6	7		
		Type of motion	22	twisting	pushing	lever	pulling				
			23								
			24								
			25								
			26								
			27								
			28								
	indirect technical interaction (interaction of part to non-human environment)	Primary material to cut	29	paper	wood	plastic	bio-mas				
		Primary corrosive mat.	30	water	foam	Salt H2o					
			31								
			32								
			33								
			34								
			35								
			36								
			37								
			38								

Figure 11: Filling in Parameters and Parameter Components in the Technical Function.



DESIGNER: PROJECT: **Design of a X-acto knife.**
DATE: TITLE:

FUNCTION	PHASES	PARAMETERS		(shows alternative ideas to parameter) PARAMETER COMPONENTS A	B	C	D	E	F	G	UNKNOWN
PRODUCTION FUNCTION	PLANNING	How many parts	39	2	4	5	7	12			
		Number in master pack	40	5	10	dozen	144				
		Tooling material (molding)	41	Aluminum	Steel						
			42								
			43								
			44								
			45								
			46								
			47								
	MANUFACTURING	Manufactured where	48	USA	Portugal	Japan	China				
		Assembled where	49	USA	Japan	China					
		Manufacturing cost	50	$.25	$.63	$1.00	$2.32				
			51								
			52								
			53								
			54								
			55								
			56								
			57								

Figure 12: Filling in Parameters and Parameter Components in the Human Function.

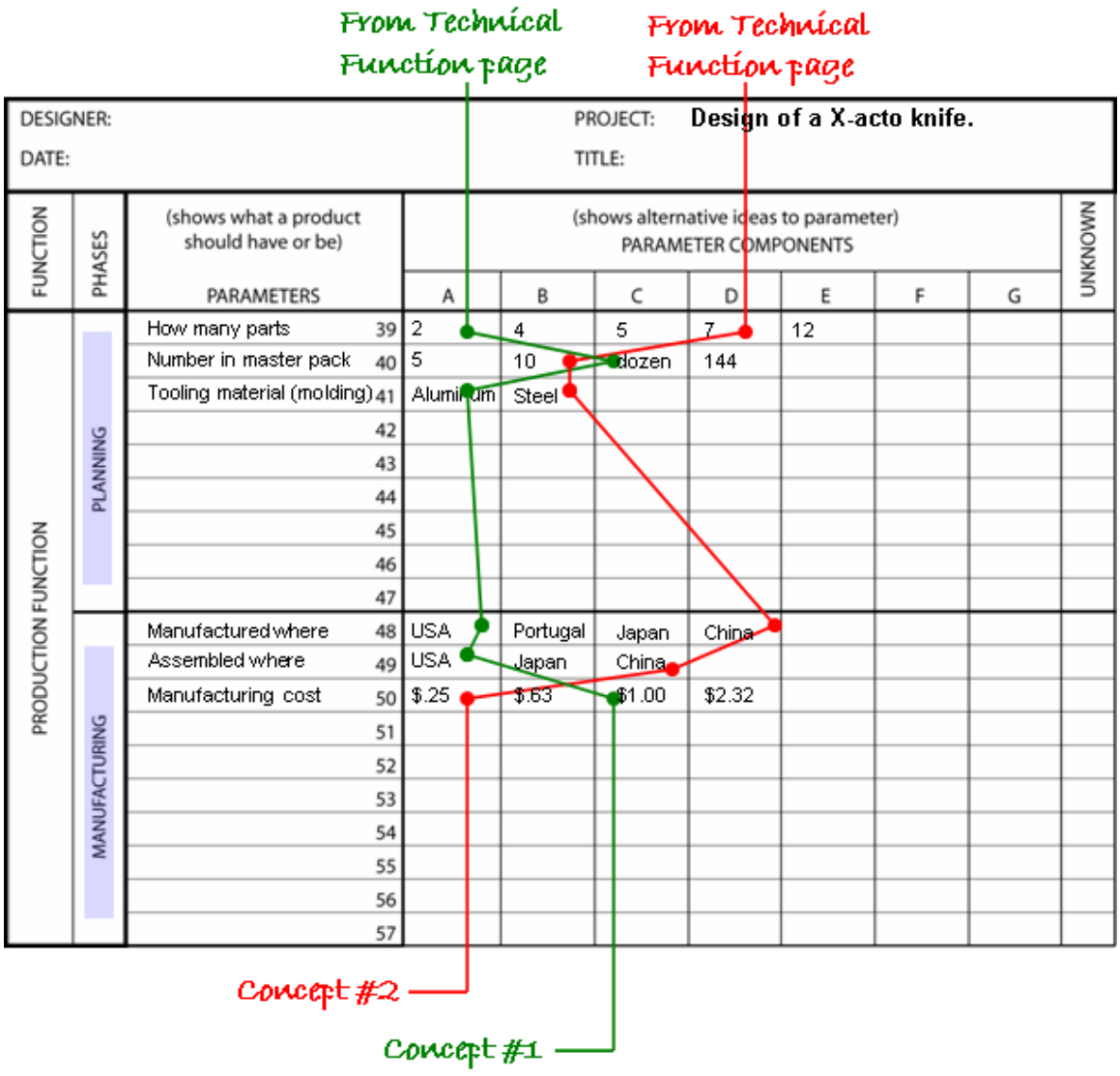


Figure 13: Concept #1 and Concept #2 developed in the Production Function portion of the matrix.

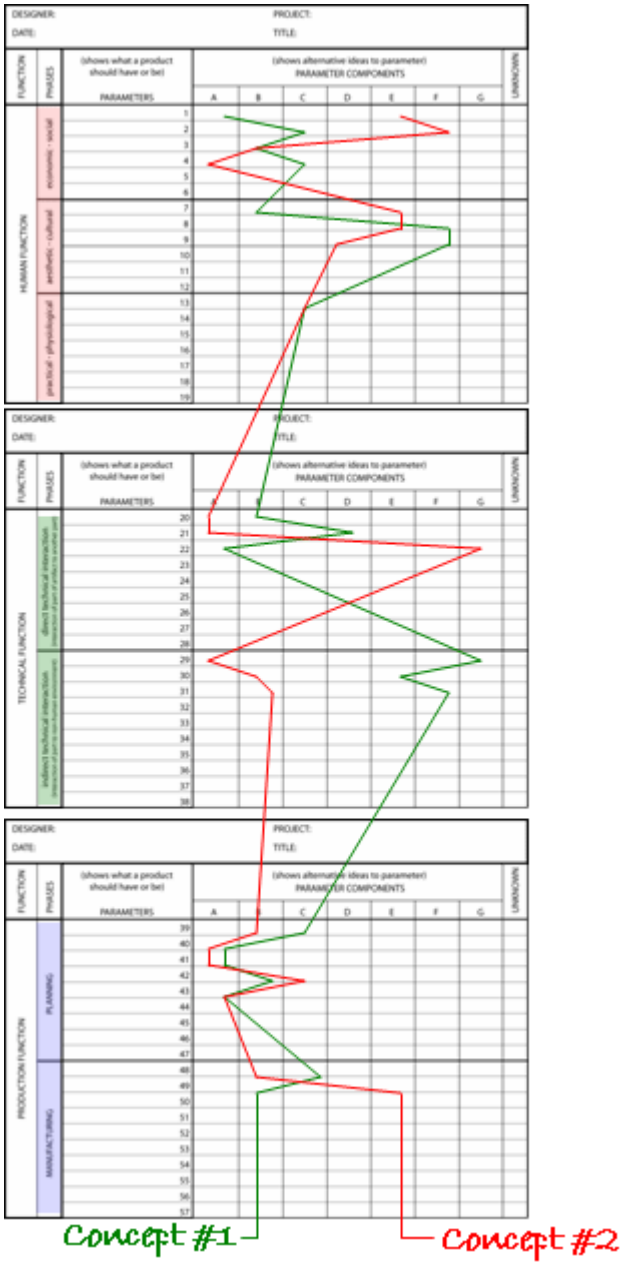


Figure 14: Two complete concepts developed in the morphological matrix.

CHAPTER 2

DEVELOPMENT OF A COMMUNICATION TOOL FOR DESIGNERS

A communication tool was developed to better manage the high frequency of information feedback and feed-forward during the design process. This tool, which is attached to a morphological matrix (see Figure 15), may assist the designer through all of the steps of the product development phases. During the Preparation (research) phase of the design process, the "researcher" gathers the data and then must pass it on to the designer for use in the Incubation phase. This information will be referred to as "researcher's input" (RI). The RI space is not the single source of research information but it could be used as the primary source of information.

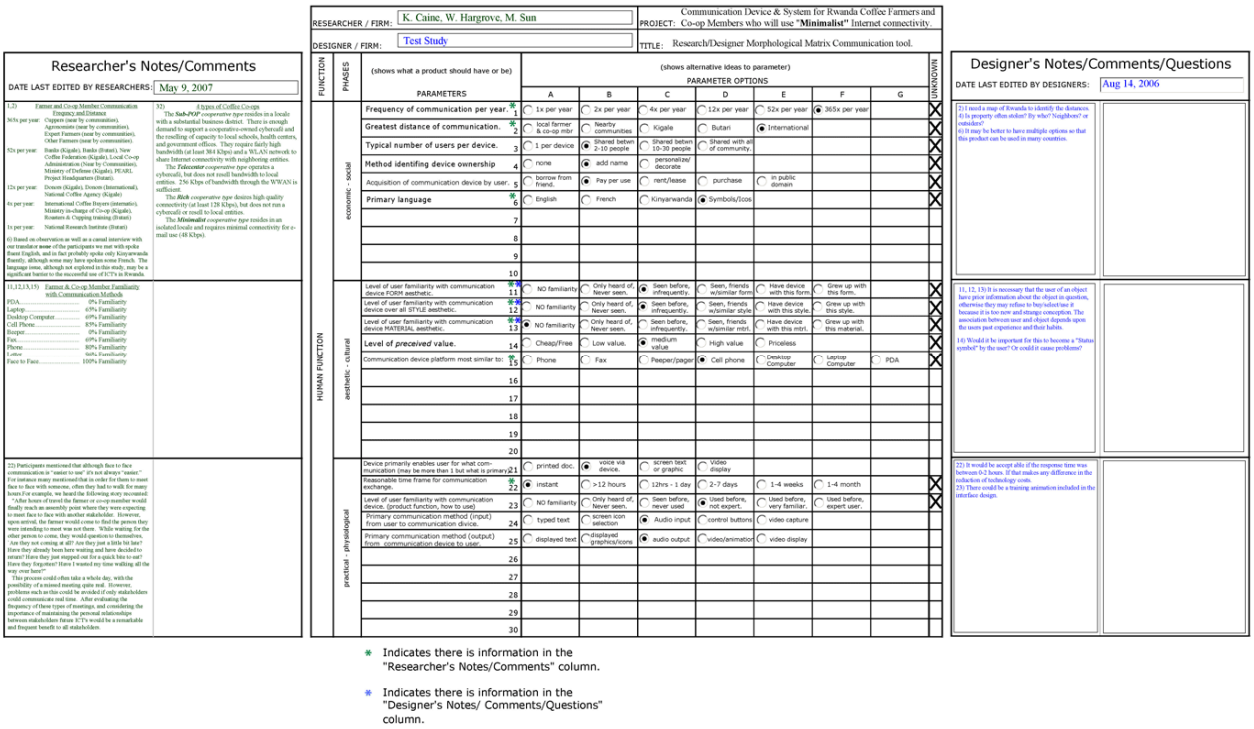


Figure 15: Modified morphological matrix with researcher's input (RI) and designer's input (DI) columns filled in.

In some cases this “researcher” may also be the same person functioning as the “designer” in the Incubation and Illumination phases. If the organization is large enough, the researcher may only be involved during the research phase with little follow through. Another option could be that the research is outsourced. In yet another complication, the research and manufacturing could be in-house and the design is outsourced to several different design firms.

In all cases, the collected data must be organized and communicated to the next phase.[Jones, 1992] The organization of the data would ideally be consistent with the structure of the design problem solving methodology. There should be a way for the designer to provide feedback to the researcher, or even to themselves as researchers. The feedback to the researcher may consist of; What additional information is needed? Why a particular solution was selected if it contradicts what the research supports? And any additional notes on any special conditions regulating selected solutions. This type of information will be referred to as “designer input” (DI). This same communication tool, with both the researcher’s input and the designer’s input, could also be passed forward down the design process path to the marketers, engineers, toolmakers, industrial engineers, etc in the communication phase.

Incorporating the RI and DI into an Existing Morphological Matrix

This RI and DI communication mechanism is being incorporated in the morphological matrix, utilizing Dr. Schaer’s Three Functions of an Artifact product/system organizational structure. This is being done because of the obvious synergistic qualities of having the supporting research information within such close proximity to all the component options are presented and the decisions are being made. The capacity of a morphological matrix to retain, catalog, and store all appropriate conceptual options and solutions in both at the component level and at the entire system level also lends itself to retaining the research supporting these options. These Parameters, Parameter options, the relevant RI, and DI can be saved for similar future design activities or as some form of proof in a legal environment.

The capability of the morphological matrix breaks down the system to the core basic Parameters which has the greatest affect of the function of the product or system. It will also allow these critical Parameters to specifically reference the relative research information, as seen in Figure 15). This break down also allows the designer to speak on the very specific Parameters that may require more information to be gathered or provided additional information to explain the reasoning behind the selected Parameter solution.

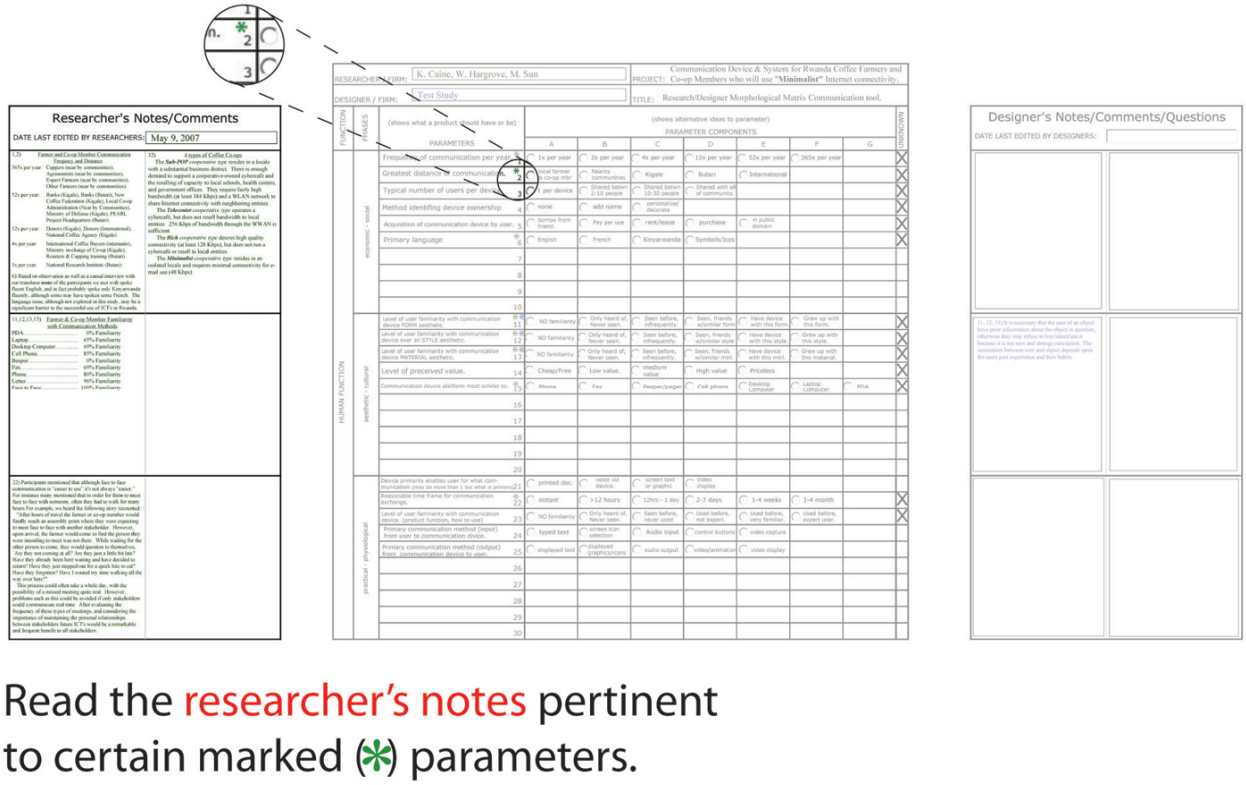


Figure 16: Parameter with * found in the Economic – Social Parameter section will have associated RI information to the left in the same Economic – Social row.

The use of Dr. Schaer's Three Functions of an Artifact structure can also be a rough structure for categorizing and organizing the relevant RI and DI. Although there may be RI located in the syntactic dimension, it could also have an affect on the Parameters located in the pragmatic dimension. When this occurs a simple cross reference note is added, as seen in Figure 17.

Proposed possible uses of the RI and DI communication mechanism.

The information the researcher gathers could come in an amazing variety of formats. The original data formats should remain, all of the pages, charts, images, etc. But once the design Parameters have been established for the morphological matrix, some segments of the research can be combed through and selected relative to the specific Parameters. This optimized research material should be most relative to the decision making process of the specific Parameter or groups of Parameters being considered by the designer.

As concepts are being developed and entered into the matrix, the designer can review the RI relative to the possible future solutions yet to be developed. Once the designer reaches the decision making point, they can use the RI to help guild their decisions.

As the designer fills in and makes selections, they can be adding their notes in the DI. These notes can be feedback to the researcher, feed-forward to the engineers or manufactures, and/or they can be used by the designer for future development.

This document can also be passed on as a tool to several separate design groups or individuals with the same basic understanding and/or training of semiotics and this chart. For an example, all of the participants of this study have been introduced to the Three Functions of an Artifact and the use of a morphological matris through a short one hour presentation. With this document all individuals will be given the same data and structure. As one group may request a

particular type of additional information, the response to the request could be passed to all groups. In the end, these entries become a library of data which can be referred back to during the post-mortem project wrap up or shared on future projects.

Filling in the original RI data.

As mentioned earlier there may be various disciples involved in the research and design process. This multiplicity of perspectives will likely increase the variety of types of data sets gathered in the research phase. The information representations may be in the forms of charts, diagrams, graphs, tables, maps, photographs, extensive written papers, books, etc.

This new communication tool is not currently designed at the depth to manage all forms of the data. Yet, because of the open space available in the Research Input data field, the graphs, pictures, text could easily be incorporated with the appropriate interface design. At this time the RI was primarily used to manage tables, lists and general text from larger documents. Future developments would focus on an interface to best represent various forms of information in such a small space.

In the beginning, there would require a single project leader or research leader to help manage the information inclusion to this chart. The subject matter should match the Three Functions of an Artifact outline structure, just as all of the Parameters are organization. If the RI is relative to the Economic-Social aspects of the problem, the RI should be placed in the RI field adjacent to the Economic-Social field. The sets of information in the RI must be associated to the number of the Parameter that it is relates to. For example if one of the RI is a list of items and this single list may relate to three different Parameters, all three different Parameter Numbers is listed next to the list. And an asterisk is placed next to each of the Parameter Numbers.

There may be information that falls in the Human Function, Economic-Social RI category that may only be relative to a Parameter # 32, found under the Technical Function, Direct Technical Interaction category of the matrix, shown in Figure 17. In this situation a cross reference note saying, “also see: Notes in Human Function, Economic-Social” would be added to the RI under the Technical Function, Direct Technical Interaction category, just to the right of the Direct Technical Interaction Parameter. The information found under the Economic-Social section will have the Parameter Number 32 shown.

The leader in charge of organizing the RI should be familiar with both the value of different types of research and the relations it would have to the specific Parameters of the problem space. But because of the dynamic nature of the feedback and feed-forward nature of this system, as designers request specific information the leader can then begin to modify the make up of the information to meet the designer’s needs. Because of the designer’s responsibility to feedback to the researchers, ideally the correct information should be brought to the surface of the RI.

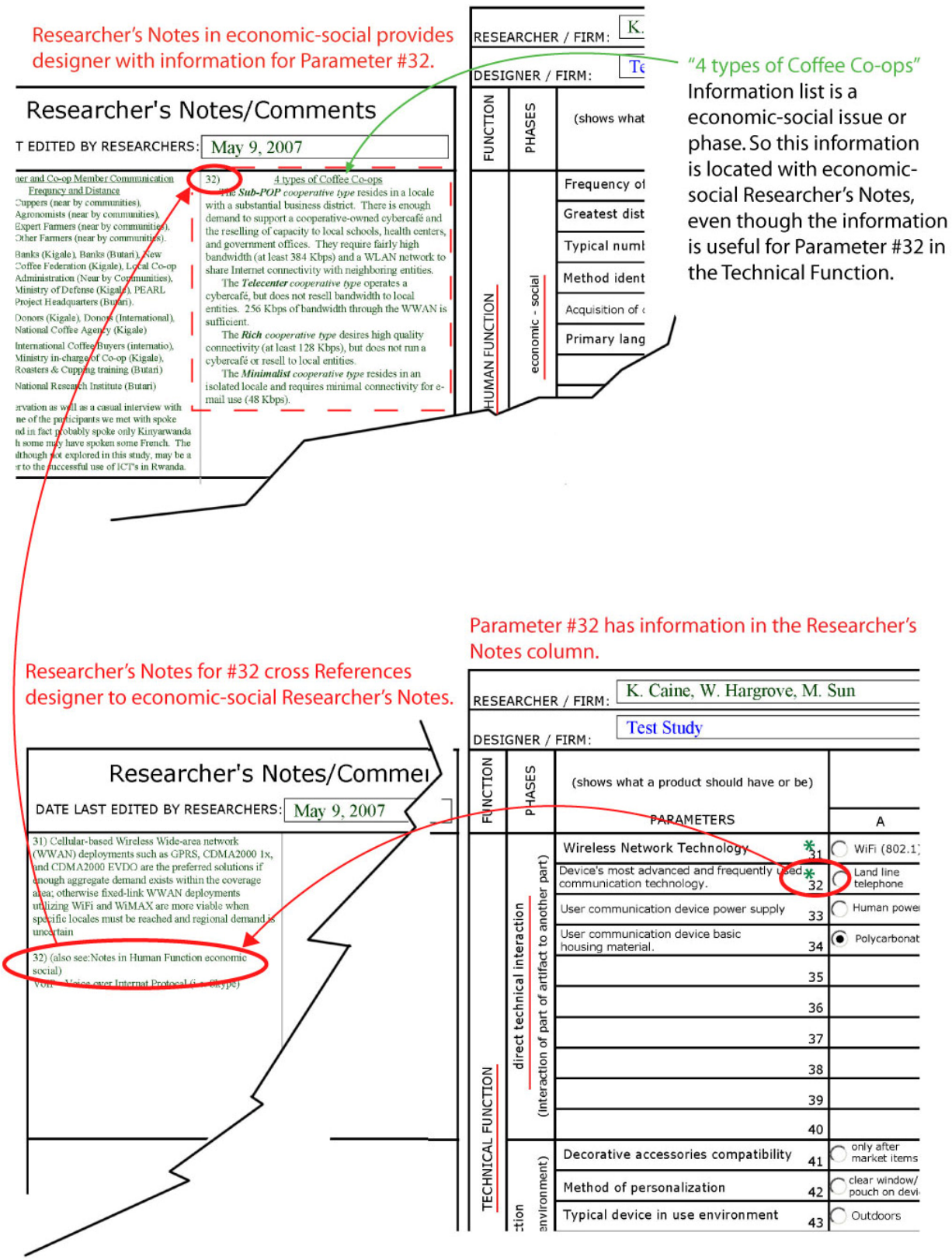


Figure 17: Cross referenced RI between Technical Function and Human Function.

Designers Using the RI Data in Decision Making

Even though the designer may also be the "researcher" who is entering the information into the RI during the Preparation Phase, this portion of the paper is referring to the designer's use of the RI during the Incubation and Illumination Phases. The designer should become familiar with all of the information available before beginning to fill in the Parameter Options or making selections of those options.

As the designer evaluates a particular Parameter, they will read over the Parameter description box and check to see if there are any additional research marks or indicators within the box. For this construction of the communication tool, the research indicator is a colored asterisk (*) near the Parameter Number. The green colored asterisk indicates that there is additional information in the RI for that single Parameter, seen in Figure16. Where as the blue colored asterisks indicate that there is a previous "designer's note, comment, or question" referring to this Parameter Number on the right hand side of the morphological matrix. If, or when, a designer finds that there is not enough information available in the RI to assist in creating or selecting the ideal solution option, the designer may place a request to researchers for more information, further research, clarification, etc. This is part of the self organizing information communication system.

Designer's use of the DI columns

Just as the researcher fills in the information in the RI and has it numerically linked to the corresponding Parameter Number, so does the designer when they add an item in the "Designer's Notes/Comments/Questions" column. The designer's input may consist of a request for more research information. Doing so perpetuates the self organizing system of feedback and the feed-forward meeting the needs of the designer.

Another use may be that the designer provides additional information or conditions pertaining to the particular solution selected. If the selected Parameter Option does not seem to match up with the information found on the RI, the designer can explain why such a decission was made. This could become very useful to designers, engineers, toolmakers, manufactures, marketing, or designers working on the future developments of a similar product.

Other uses for the RI and DI.

Because both the RI and DI information are organized using the Three Functions of an Artifact structure this information can be passed down to other evaluation charts using this same Three Functions of an Artifact structure for other possible organized evaluation charts. An example would be a Right Wrong Chart or an Analysis Evaluation Checklist. Both of these types of charts might be beneficial during evaluations.

Not only does both the RI and the DI sets of information become a useful record for a post mortem, this information could be stored and retrieved for applications in similar future projects, or as a type of evidence in a legal environment. Naturally the product form, functions, features do change while being developed and this record could track those changes. This information system becomes the history blog of the product's development and life.

Interface design of RI and DI.

The extent of the development of this communication tool was limited to the RI and DI application, core functions, and organization methods. Much of the interface design is still required but the concept of using the Researcher's Input and Designer's Input in the Morphological Matrix has shown great benefits. Some initial considerations regarding the interface could begin with the accessing various types and densities of information. At this time there is some static screen real estate available for text. In the future, this open field could be

reduced to particular icons that, when one is selected, could open to present a higher volume of information. Perhaps these icons or access points could be placed within the very field of the Parameter description. Although one nice feature of the open field is that it covers the entire area of the "Social-Economic" section and provides the availability of the RI information to all of the Parameters listed under the "Social-Economic" phase.

As the product/system development process continues through several cycles of feedback and feed-forward, a more sophisticated dating system for each entry may be required. Currently there is a date for "latest editing" but perhaps color coding or other methods could also be helpful.

The question of graphics is also an issue and will be considered critical in the design and effectiveness. But just like the morphological matrix is capable of also receiving images, so would the RI and DI section. As they are now, there are two panels for each section. One could primary handle graphics, charts, photo while the other section text. This type of interaction development requires further development.

Now the question is: "How will it really work?"

After this detailed description of how the RI and DI are laid out and how it could be used by the researchers and designers, the theory based methods were tested. The tests will be from the designer's perspective and how the designer will use this modified morphological matrix. There have been many hypothesis mentioned in this last section and the following chapters bring to light the effectiveness and application for actual use.

CHAPTER 3

METHODS

A test to examine the use of the RI and DI in a morphological matrix was developed for a group of beginner participants. A blank modified morphological matrix, found in APPENDIX A, was filled in with data from two researcher paper. These participants must have had previous exposure to both the Three Functions of an Artifact, which was the basis of the organization of the charts, and the use of a basic morphological matrix, which requires knowledge of how to operate the chart to gain their desired design results. Fortunately there was a large group of students that had just completed a project which utilized both of these tools in a studio course. There were several others who had both key components presented previously in classes and during professional organization conferences. Anyone who has gone through the training session made up of two series of presentation slides should have a grasp of the larger concept of how this tool was to function and how the information would be structured. An additional review was built into the beginning of the testing materials, shown in APPENDIX B.

The participants were regularly notified in class and during the organizational meetings that this study was going to be made available to them if they would like to participate. The study was placed in a public location in the school of architecture for their access and the results were to be returned to the same location. This resulted in having 38 participants in this study.

What is Being Tested.

Three primary areas of attention were the focus of these studies. First being the accuracy of the designers results based on the available data in the study. The second area was to check

how the participants may have used the DI if they had used it at all. The third area of focus was to evaluate what the perceptions of usefulness was for the designers.

Construction of the Experiment.

In the past many participants had used a morphological matrix, outlined by the Three Functions of an Artifact, within the scope of an industrial design project. All of the participants had seen the presentations, presentations materials enclosed in (APPENDIX B), covering the Three Functions of an Artifact and the use of a Morphological Matrix at least once.

There were two scenarios given to the participants in the testing material. The first was placing the participant in the scenario of being a designer for a project and the typical flow of information from researcher to designer and designer forward to production. It was said that the flow of information would include several feedback loop opportunities and in the end the most refined solution would move forward to manufacturing. This was to establish or remind the participants of the macro problem solving environment.

The second scenario was one to describe the complex problem they were to solve. This scenario was based on a real complex problem of meeting communication needs for the Rwanda coffee farmers and co-op members. Because of the obscurity of the topic the likeliood of participants basing their answers on their previous knowledge of the subject, rather than relaying on the research data provided, maybe greatly be reduced. This lack of preconceived solutions or scenarios was a benefit to the study.

This Rwanda data used in the second scenario and in the RI, DI, some Parameters, and the Parameter Options, was collected from two unpublished papers on Rwanda Information Communication Technology (ICT) in Rwanda. The Rwandan ICT researchers spent an entire semester studying ICT for economic development and then traveled to Rwanda for several weeks

to collect data. The first paper by Mike Sun, a Georgia Institute of Technology Electronic and Computer Engineer PhD candidate, was titled "Connecting the Rwanda Coffee Cooperatives: Economic Analysis of Network Deployments for Rural Rwanda."[Sun, 2006] Much of the information relative to the design areas of Production Function and Technical Function was drawn from this paper (APPENDIX D). Examples of the Technical Function and Production Function information would be which type of telecoms or ISP would be best used to provide services or what wireless network technology would serve best.

The second unpublished papers was co-authored by Kelly Caine, an Industrial Psychologist PhD candidate, and Walter Hargrove, a master of Industrial Design candidate. The paper's title was "Information Communication needs of Rwandan Coffee Stakeholders" [Caine, Hargrove, 2006]. Much of the Researcher's Input for the Human Functions was gathered from this paper (APPENDIX E). Examples of the information addressing certain Human Function Parameters would be about familiarity of communication devices or the primary languages spoken.

The use of these two papers reduced the test creator's bias on the test information being used. It was all based on a very real situation and created by multiple researchers of multiple disciplins. Because the information being placed in the RI portions of the modified morphological matrix was being added by an actual researcher who was a designer familiar with the chart, this brings a higher level of reality or validity to this research scenario.

A single input on the DI side was a "note" referring to familiarity and acceptance of an artifact by users was added. This was done to add to the perception that this document has already gone through one feedback cycle earlier. This note had been taken from an article published by Idea/Journal by Walter Schaer:

> "It is, of course necessary that the user of an object have prior information about the object in question, otherwise he may refuse to buy it because of its too new and strange conception (lack of necessary redundancy). We know that the association user-object depends upon the user's past experiences and his habits (recognition)."[Schaer, 1963]

This single DI input, provided by an "outside designer", also provides a bit more information and complexity, when in combination with the available RI information on the same subject, to guild the participant designer in making a selection of three individual Parameters.

Even though the total Parameters were few in number, the complexity variation of use was quite high. The RI information, Parameters, Parameter Options, and the single DI note was arranged in such away that a variety of complexities would be present. Examples are having multiple Parameters using the same sets of data. A Single Parameter may have information in both the RI and the DI. Parameters in the Technical Function may be cross referenced to information found in the RI of the Human Function portion. This complexity would require the participant to use the document to identify find the solution.

The Parameters that had information available in the RI for the participant designers also had the Parameter Options pulled from the Rwandan Papers. These possible solutions were also being considered and evaluated in the Rwandan papers. The remaining Parameters were simply created to fill out the document and provide additional reality to the scenario problem.

The participants were given this filled in morphological matrix to simply select the single option they would consider as the best solution. They were led to believe that this was only one of the initial concepts development rounds and that further development would, occur by others, after their work was finished. They were also encouraged to take advantage of the research that

was currently provided when making their decisions, rather than going on their best guess. They were told to complete one design concept by selecting one option for each Parameter. During the Parameter Options selections, the participants were encouraged to provide input to the system as the designer. They were also presented the location of the "Designer's Notes/Comments/Questions" field.

In the end, there was a short questionnaire, found in APPENDIX B, regarding their perceptions and experience of using the modified morphological matrix. This questionnaire was broken down into four Likert scales measuring the level of familiarity of a morphological matrix, how helpful the provided RI notes were in their decision making, the comfort level of the decisions they made, and how useful their DI would be to other members of the development team.

How to Score the Results.

Three different types of information were taken from this research study, found in APPENDIX C. The first was to capture the percentage of correct scores to six particular Parameters that were spread out in various phases of the matrix. These Parameters were selected to be scored based on the correct solutions that could be found only by using the data provided from the two Rwandan research papers much of this study was built around.

The second type of information was by tabulating the input use, which phase and what number of different inputs the participants placed in the DI. Further information about what type of inputs and who applied any DI at all was collected in the questionnaire.

The third type of data collected was the participants' perception via Likert scales. And used to simply create a context of the users of this new feedback system in the design process.

Success Rate of the Tool in Problem Solving

The actual Rwandan researchers developed the conclusions to their papers based on interpretation all of their highly detailed data. The participants' conclusions were developed completely from the designer's interpretation of the much smaller volume of data provided in the RI. The actual Rwandan researchers' conclusions will be marked on a chart and be over laid by participant aggregate data. This will track if there is any similarity in the solutions given the two different arrangements of information, and the two different levels of familiarity to the Rwandan problem environment.

The Examination of How the Designers Used It.

The participant designers' notes, comments, and questions will be categorized based on what type of statement it is. Is it a question to other designers and to the researchers? Is it a comment about the Parameter Options selected for future development stakeholders like other designers, engineers, marketing, or manufacturing? Did they have suggestions of specific types of information needed or simply wanting more information?

If data found in the DI area was directed to the creator of the morphological matrix that would simply be placed under the participants' input area of the final questionnaire. Similarly, if the participant placed data in for the answer to question number seven that actually was addressing a Parameter, that information would be organized under the appropriate ID input field.

Perception of its Usefulness

The perception of usefulness will be derived from the questionnaire data set. A copy of the questionnaire is provided in (APPENDIX B). It is made up of four Likert scaled questions, one yes/no questions, and a single open ended question.

CHAPTER 4

FINDINGS

The research data collected was organized based on the Theory of Signs. The sign vehicle was the modified morphological matrix and questionnaire. The first portion of research was with in the semantic dimension as it examined the single selected concept of the Rwandan coffee farmer's communication device. The over all meaning of the solution was developed by selecting a solution for each Parameter. What was the quality of this meaning?

The second the set of findings were exploring the syntactic results of the participants use of the RI and DI feedback mechanism created for this given Rwandan project. Where did the participants place their input? What was it linked to? What Parameter did the designer assign the input they provided? Did the DI refer to something already with in the current feedback system or was it asking for new information outside of the system?

The third portion of the research and findings was to identify the pragmatic or human function of use of the sign vehicle in the design process. Did it perform as a helpful tool to the designer, would it be helpful to the other members of the design team? What was the level of familiarity of this too the designer? These findings, because of the holistic semiotic approach, thoroughly describe the feedback mechanism used in this morphological matrix in complex problem solving.

Success Rate of the Tool in Problem Solving

To measure the success rate of the participants selecting the correct option in the morphological matrix, only six Parameters were chosen to be scored in the morphological matrix. Only the Parameters, which correct answers can be derived from the RI data submitted

from the two referenced Rwandan studies, were scored. By taking these six critical Parameter Numbers there is a 1 out of 7561, or a 0.013%, chance that all six correct solutions could be found.

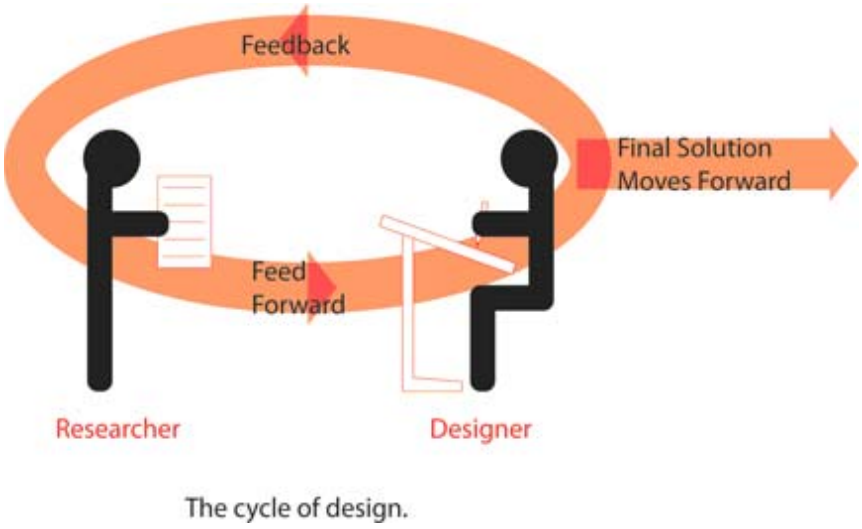


Figure 18: Cycle of design process between researcher and designer.

Because this study was only a snapshot of a single cycle design process, found in Figure 18, but also allowed input from designers to feedback to researchers, there is still an opportunity for the researchers feed-forward requested information that would assist the designers to select the correct answer. When scoring, if the designer picked the wrong answer in the critical Parameter but also provided input in the DI column referring to that specific Parameter, the answer was not marked incorrect. This is because the design cycle allows the opportunity to select the correct answer in the next round. With the ability or willingness of the designer to record the DI, the feedback keeps the design process alive. If the designer selects the wrong answer and does not provide any feedback to the researchers, the opportunity for new information dies along with the opportunity of selecting the correct solution.

After scoring each of the thirty five participants six critical Parameters, we found that 83% correctly selected two thirds of the answers correctly and 50% had selected five out of the six critical Parameters correctly. This is quite remarkable seeing how none of the participants had ever read the research data collected in the two new Rwandan research documents.

How the Designers Took Advantage of the New Tool

Simply making correct selections to the Parameters was only a portion of this study. The designer's use of the RI and DI tools was also being measured. The correct selections of the six critical Parameters, which could only occur by the use of the RI, are a way of measuring the utilization of the RI's.

The number of participants who used the DI was recorded in the questionnaire along with the reasons why some designers did not add any Designer Inputs. According to the results 77.1% of the designers did make use of the DI. There was also a space allowed for the participant to explain why they did not use the DI. The two participants responded with the thought that they did not believe their input would be much help. This could be an indication of a participant with less design experience.

Another measure broke down the DI use into the seven phases, such as economic-social, direct technical function, planning or manufacturing, had designers provided inputs (see Figure 19). The final measure scored the designers who did use the DI, by finding the average number in different inputs per DI phase shown in Figure 19.

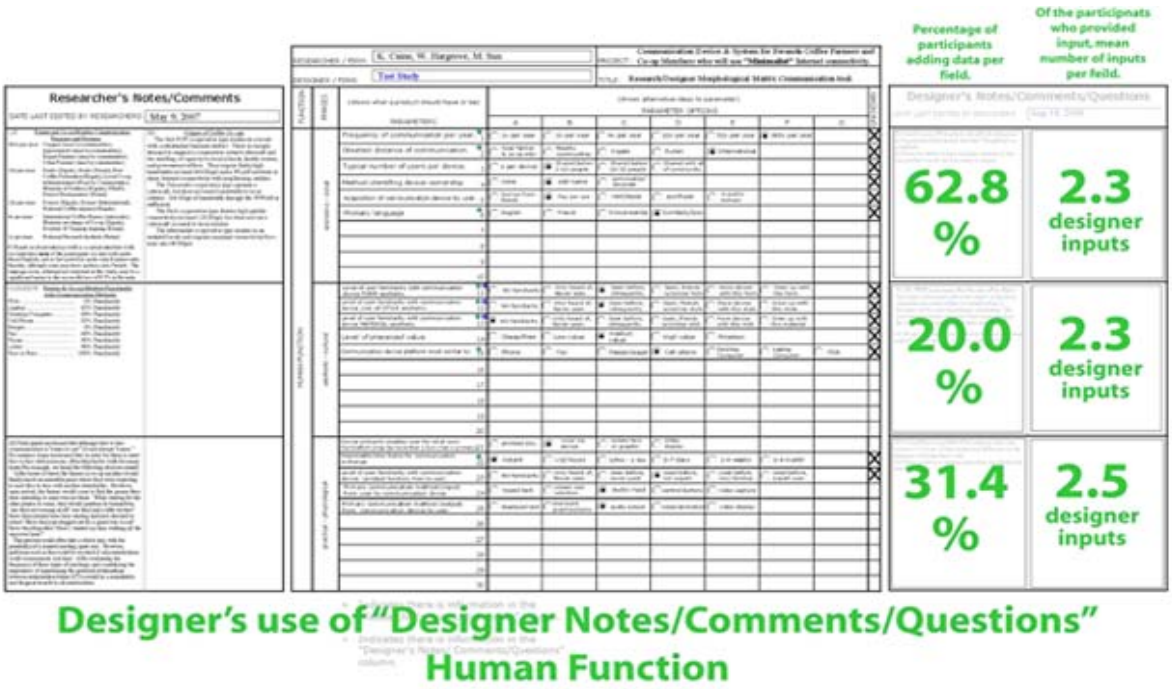


Figure 19: Percentage of participants that provided input and how many inputs in the Human Function DI.

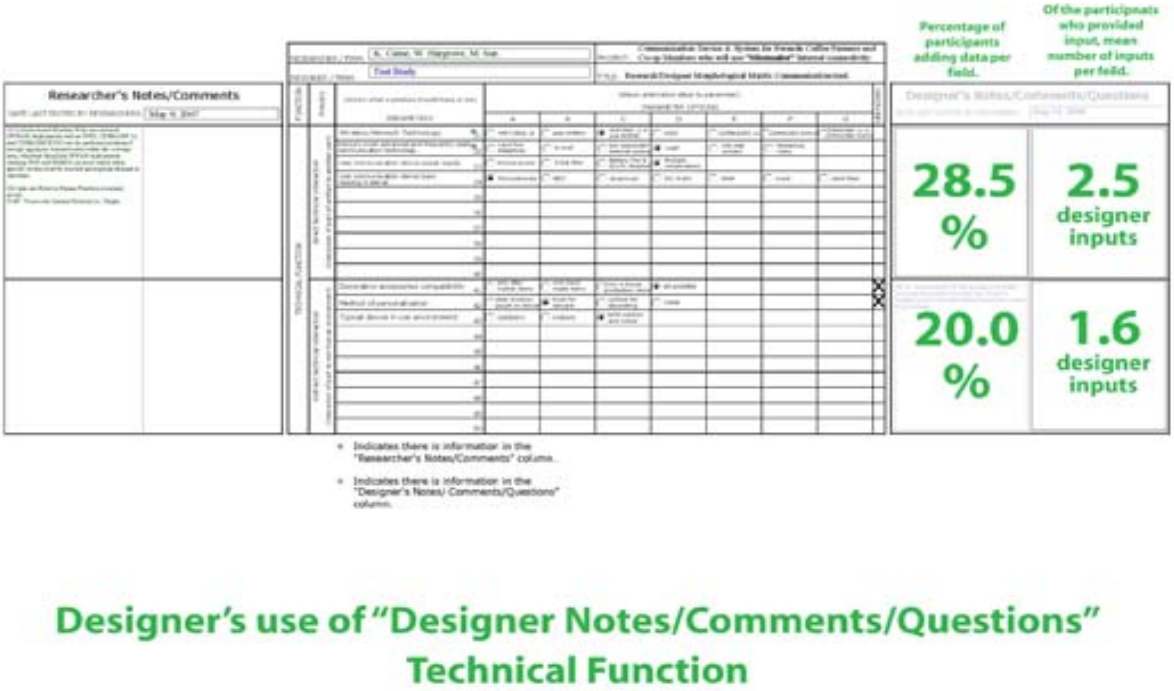
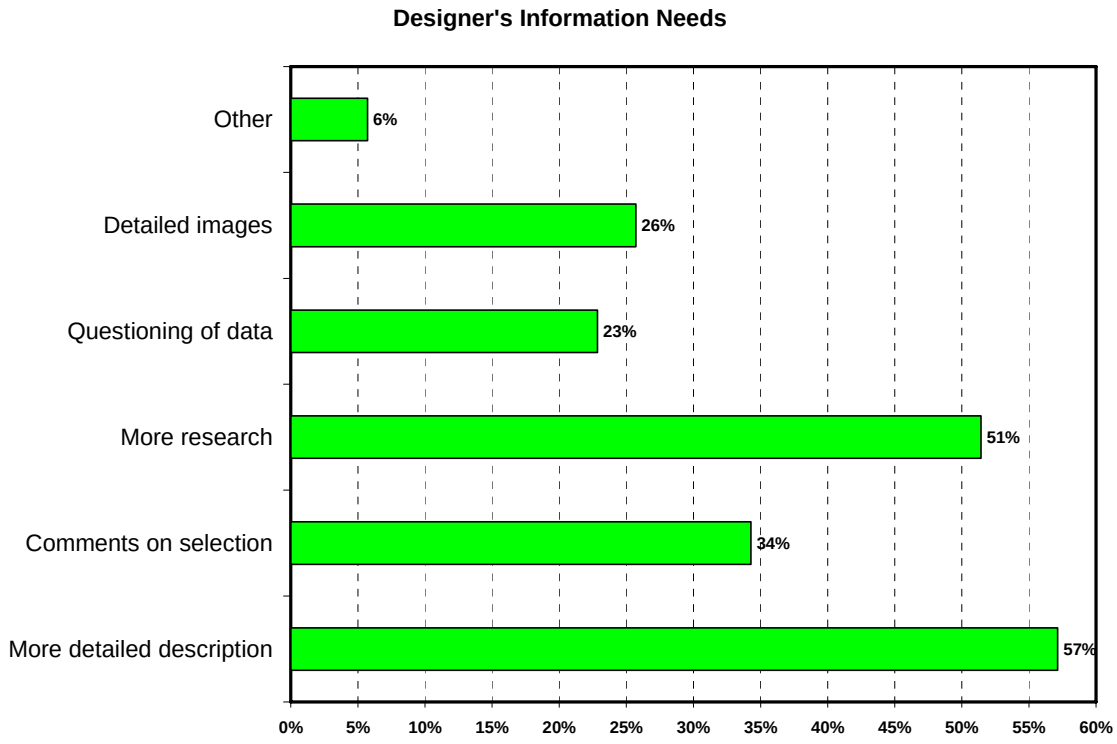


Figure 20: Percentage of participants that provided input, and how many inputs, in the Technical Function DI.

Figure 21: Percentage of participants that provided input, and how many inputs, in the Human Function DI.

The types of information the designers wanted to provide in the DI was recorded in question six of the questionnaire, seen in Table 2. Question six provided five predetermined options of types of information that could be added to the DI. Three "other" categories were also available for the designer to fill in any additional, unlisted type of information. The four participants who responded with an "other", stating that they generally wanted more information or more background information.

Table 2: Designer's information needs



The Perception of its Usefulness

Four questions sought out the participant's perception of the familiarity with the use of a morphological matrix, the helpfulness of the RI when making their decisions, comfort level of making decisions, and the helpfulness of their DI to other members of the development team.

According to the participants self rankings of familiarity, helpfulness, comfort levels, and usefulness, the following key findings were found:

- 44% of the participants felt like they possessed little or no familiarity with the use of a morphological matrix. While 50% participants were familiar to extremely familiar with the morphological matrix.
- 82% found the "Researcher's Notes/Comments" where helpful in making decisions.

- 63% of the participants were uncomfortable with making decisions.
- 67% thought their input as designers would be helpful to other members of the development team.

The combination of the facts that 44% participants felt like they were unfamiliar with the system, and 63% were uncomfortable with their decision remarkable when one considers that 82% thought that their inputs would be helpful and that 83% correctly selected two thirds of the answers, and 50% had selected five out of the six critical Parameters correctly. This shows the success of this new system.

CHAPTER 5

CONCLUSION

The RI and DI communication mechanism, which are sets of consolidated information focused on particular Parameters of the problem space, can be used successfully in complex problem solving. These successes include a holistic and universal organized methodology, using the semiotics and the Three Functions of an Artifact to structure research information for decision makers. The designer has a higher likelihood of good design solutions to complex problems, even though the designer may have limited or no previous experience to the problem context, when using the provided RI and DI. The designer took the opportunity to feedback requests and gain the appropriate information needed from researchers. The designer also provided useful information to the development team needed further down the design process.

Other Applications

The RI and DI columns can also be applied and be beneficial to other problem solving charts that uses the Three Functions of an Artifact as a structure. These charts maybe useful during product development, product evaluation, and product documentation steps of a project. Other than the morphological matrix, examples of charts that can use the similar semiotic structure are an analysis and evaluation checklist, a right-wrong chart, and a comparative product chart. Both the RI and DI may be able to explain, record, or remind why certain decisions during the use of any of these charts.

All of the recorded RI and DI can be stored as a permanent and dynamic project record. Information can be added at any time or copied from this document and applied to future similar

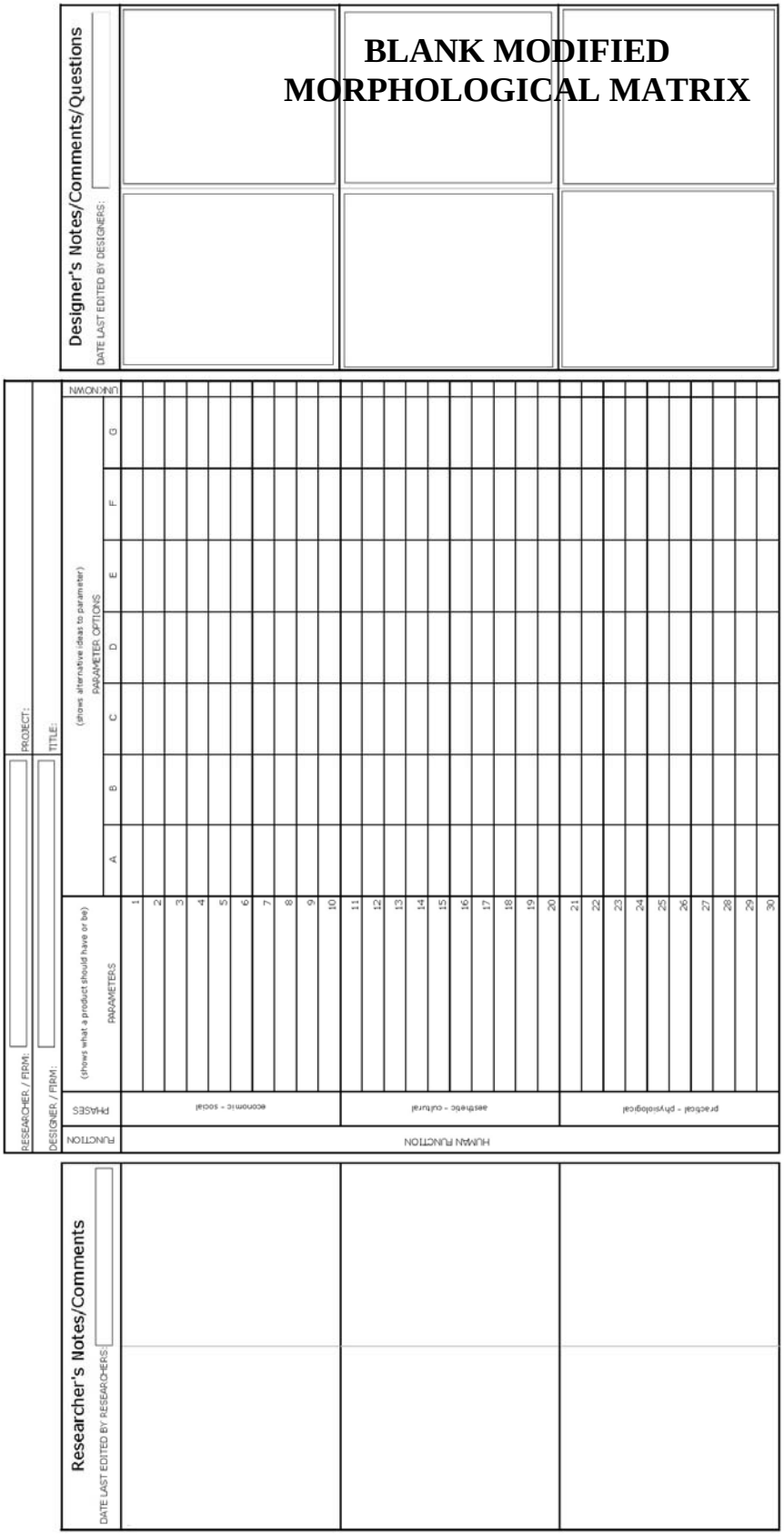
projects. This document should not be the single all inclusive record of the entire project. A more complete project report should be maintained that goes beyond this researcher and designer feedback and feed-forward communication. [Ullman, 2003]

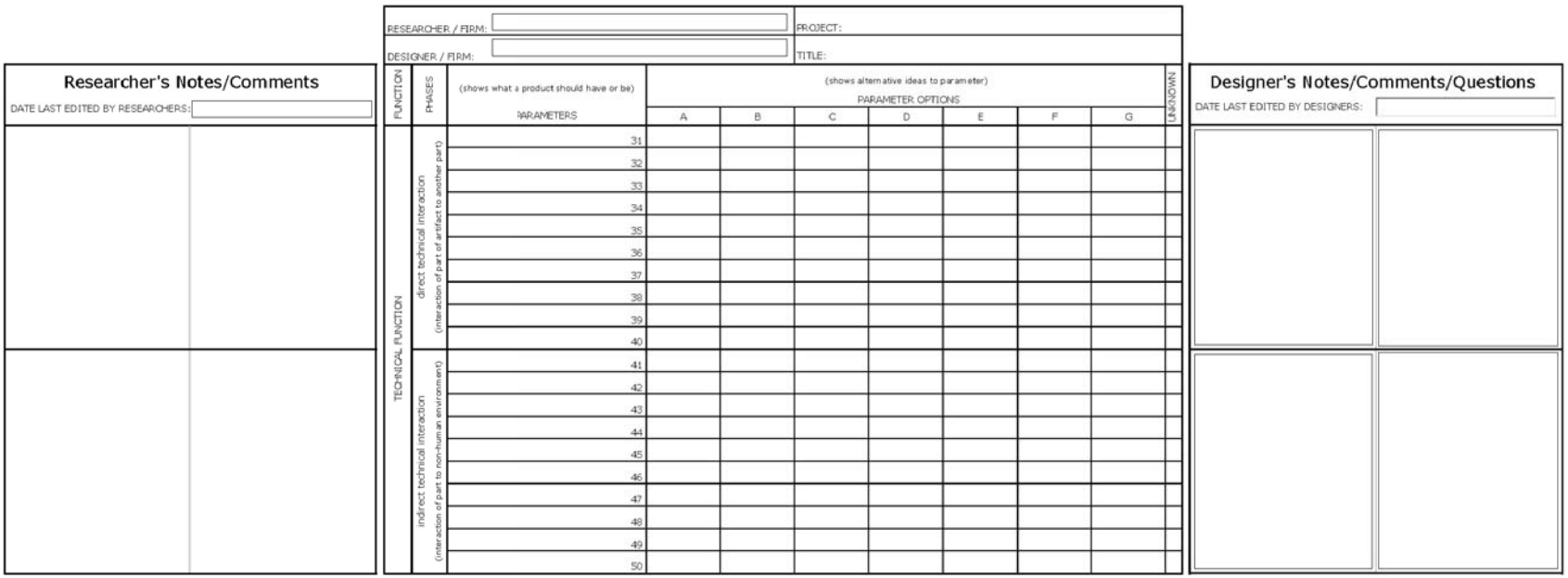
Future Studies/Research/Nest Steps

This study only tests the concept of the RI and DI communication mechanism. Much further work is needed to bring the concept up to a higher level for actual use. One aspect of the development of this feedback recording mechanism that was not addressed is the user interface design. This chart only used information in a text format. The static text fields were difficult to read or require a good deal of zooming and panning of the document. The ability to have links, symbols or icons to connect the user to the information could be explored. The incorporation of graphs, charts, sketches, photographs, and other static or dynamic forms of presenting graphic information is greatly needed. If I further my development of this tool, it will be in the area of user interface.

APPENDIX A:

BLANK MODIFIED MORPHOLOGICAL MATRIX





* Indicates there is information in the "Researcher's Notes/Comments" column.

* Indicates there is information in the "Designer's Notes/ Comments/Questions" columr.

RESEARCHER / FIRM:

DESIGNER / FIRM:

PROJECT:

TITLE:

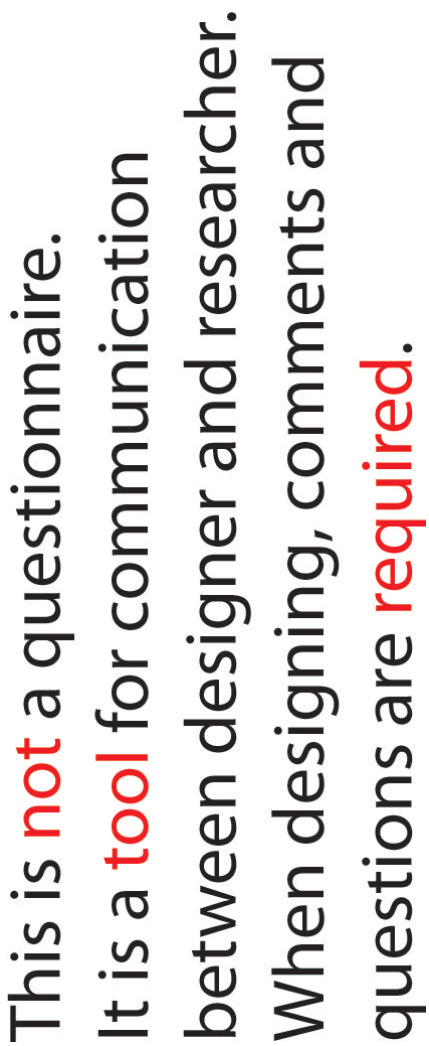
Researcher's Notes/Comments	FUNCTION	PHASES	(shows what a product should have or be) PARAMETERS	(shows alternative ideas to parameter) PARAMETER OPTIONS A	B	C	D	E	F	G	UNKNOWN	Designer's Notes/Comments/Questions
DATE LAST EDITED BY RESEARCHERS: May 9, 2007												DATE LAST EDITED BY DESIGNERS:
	PRODUCTION FUNCTION	planning	51									
			52									
			53									
			54									
			55									
			56									
			57									
			58									
			59									
			60									
		Manufacturing	61									
			62									
			63									
			64									
			65									
			66									
			67									
			68									
			69									
			70									

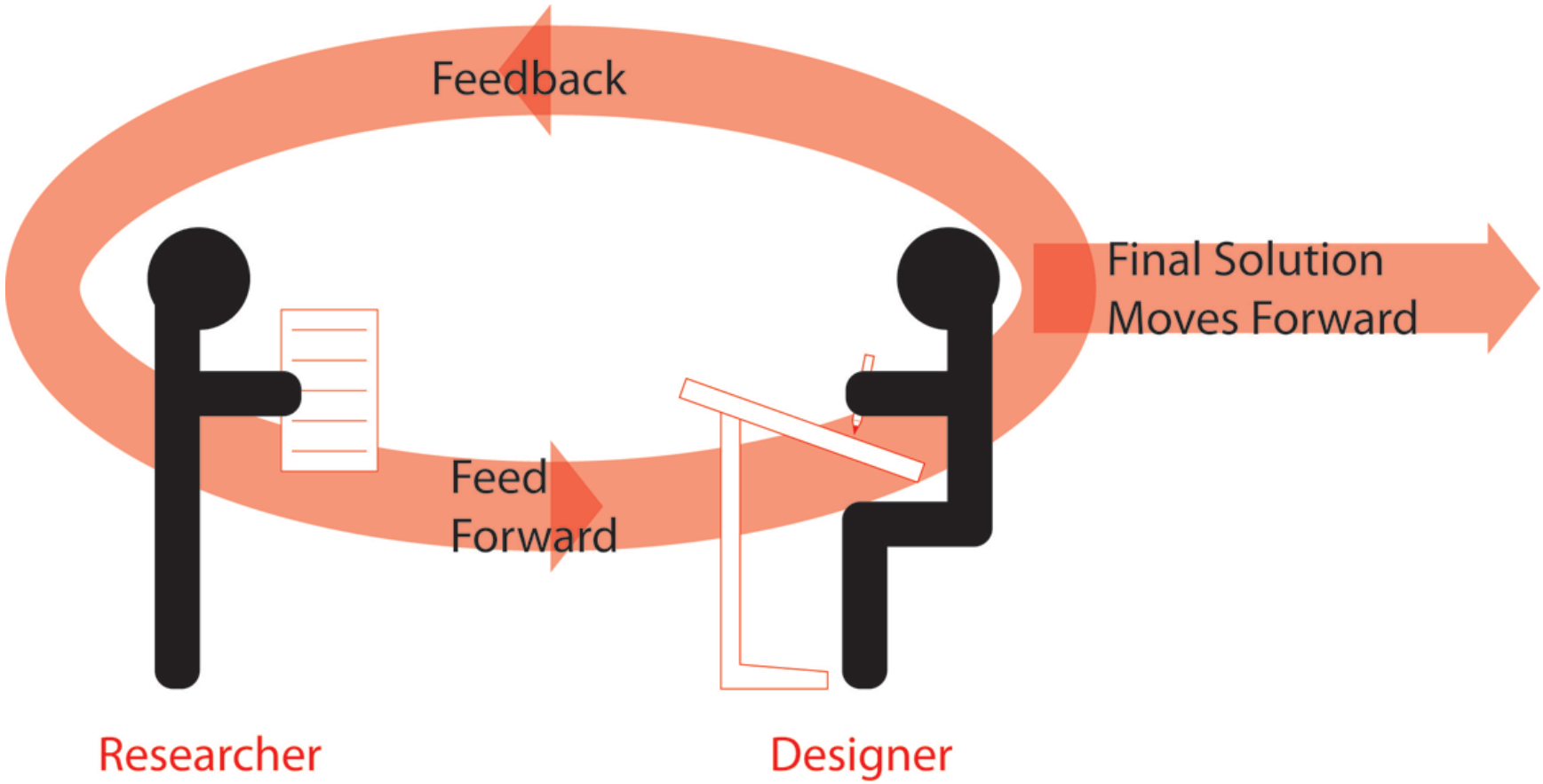
* Indicates there is information in the "Researcher's Notes/Comments" column.

* Indicates there is information in the "Designer's Notes/ Comments/Questions" column.

APPENDIX B:

SAMPLE RESEARCH STUDY
(FILLED IN BY APPLICANT)



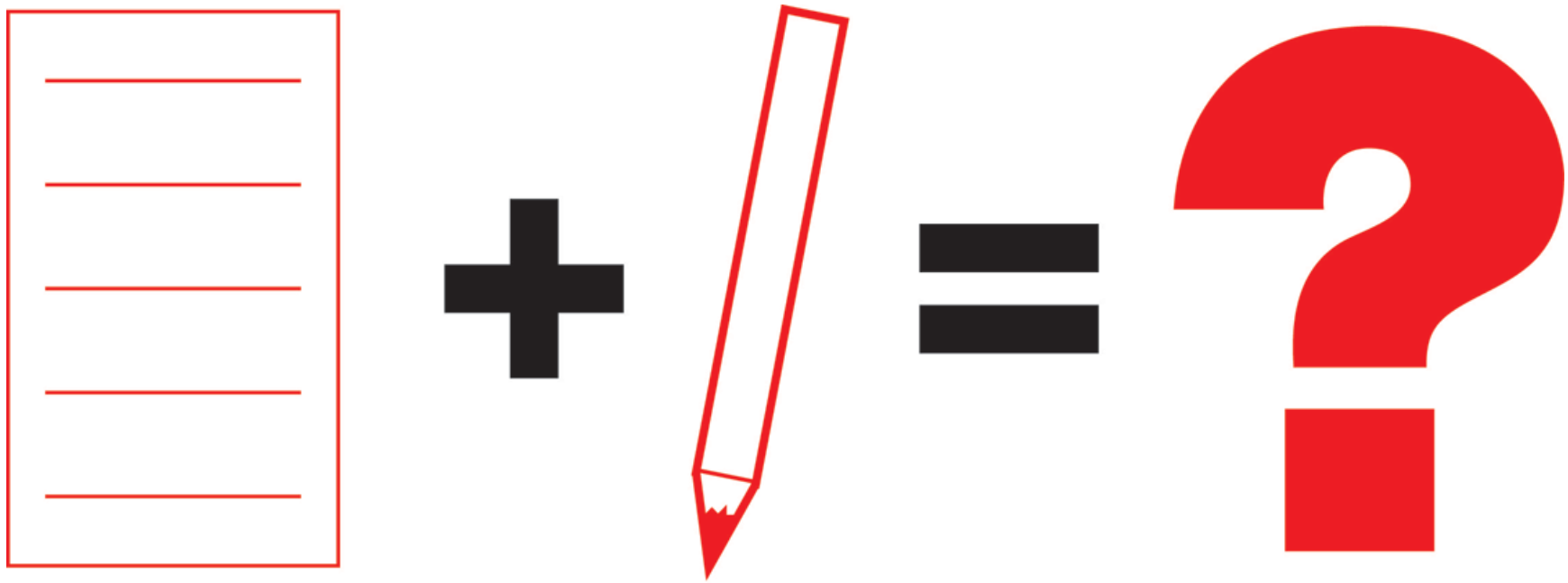


The cycle of design.

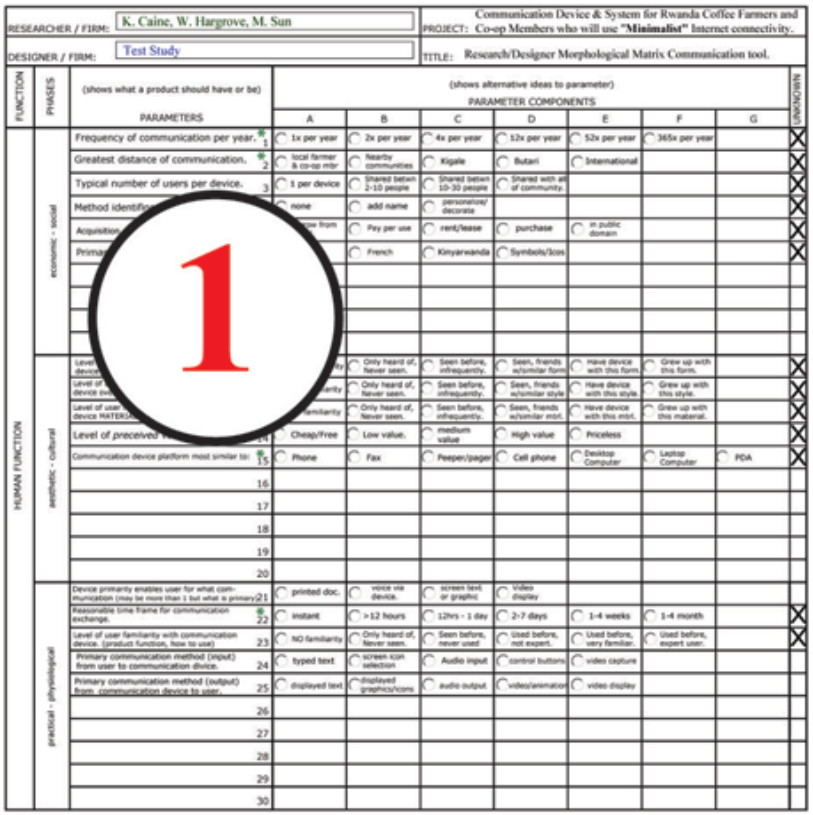
The example is a case study
on coffee cooperatives in Rwanda.

The researcher provides information on
the country, industry and farmers.

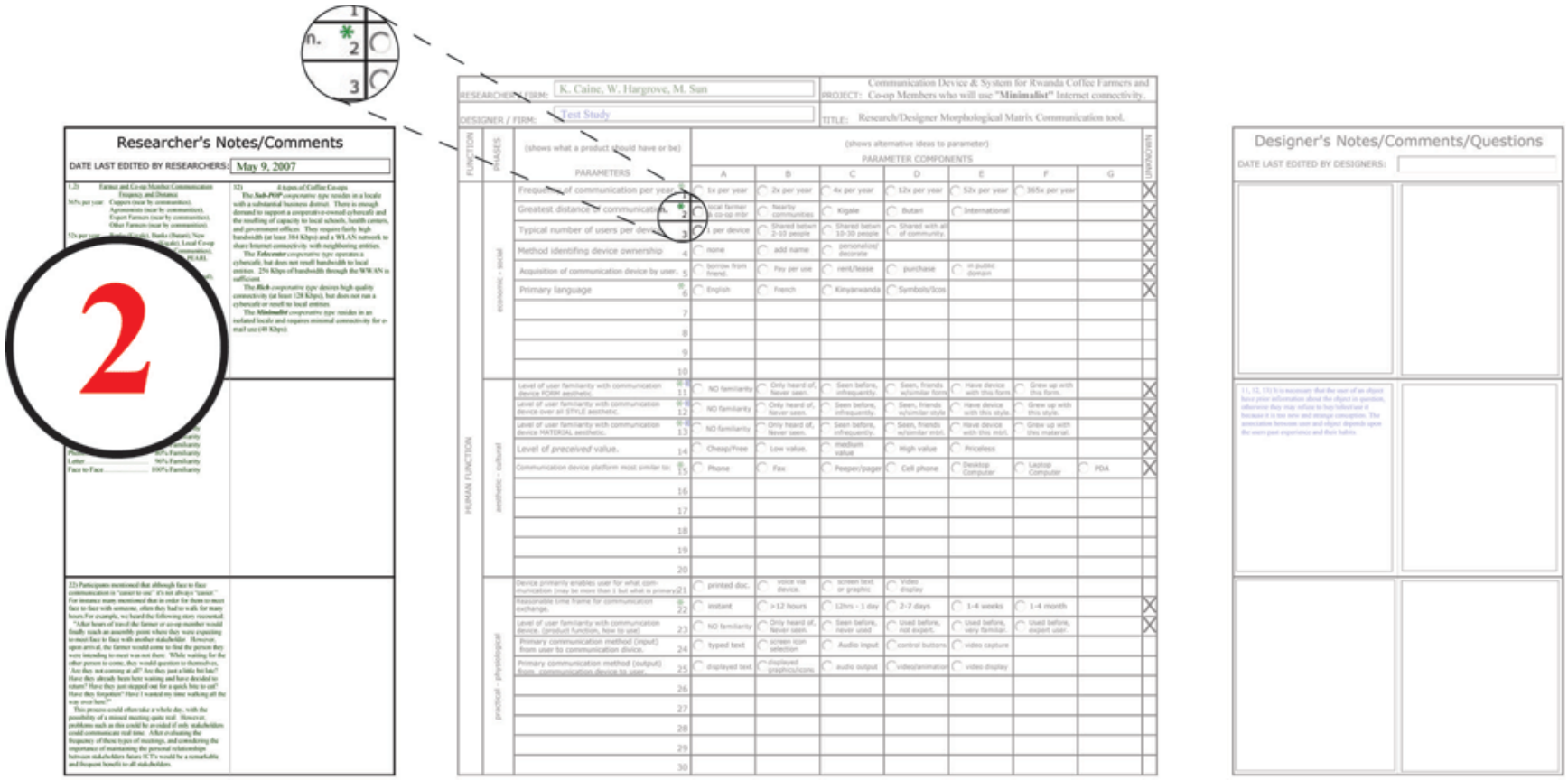
The comments and questions
you provide are feedback to the researcher.



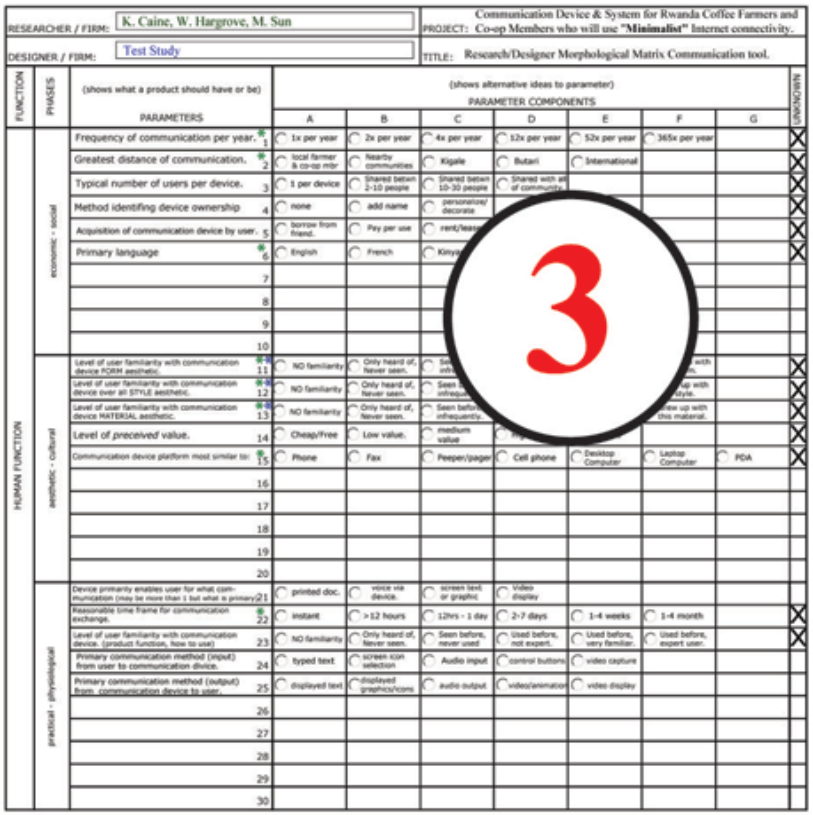
Research Design Solution



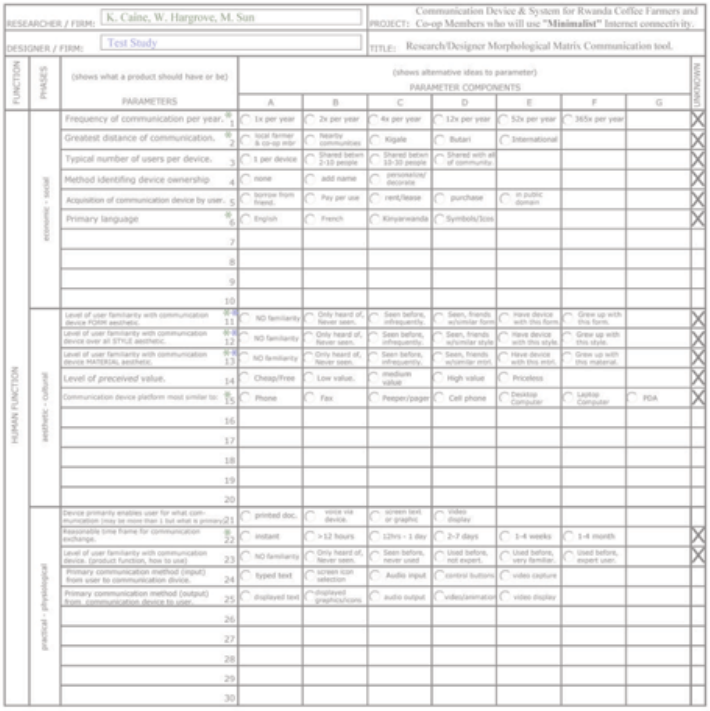
Read the numbered parameter and the design options provided.

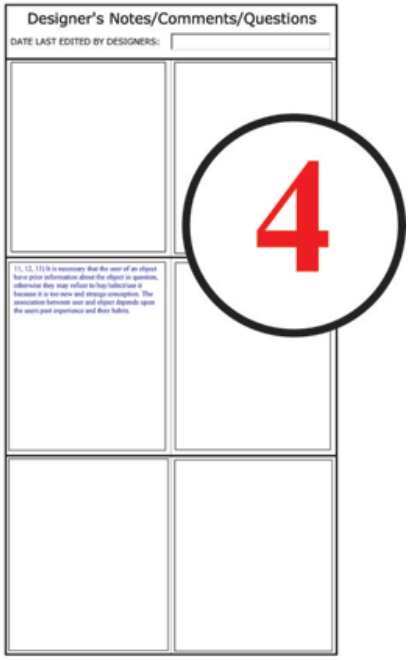


Read the researcher's notes pertinent to certain marked (*) parameters.



Select what you determine to be the best design option for the parameter.





You have an opportunity to provide: Requests for additional info you need. Is there another option you would recommend? Do you have a question for the researcher?

The design process begins here.

In this example the researcher provides information. You, the designer, make decisions and comments based on this information and then communicate it back to the researcher.

In the real design scenario this happens mulitple times until a solution is reached.

Good communiation is good design.

RESEARCHER / FIRM: K. Caine, W. Hargrove, M. Sun

DESIGNER / FIRM: Test Study

PROJECT: Communication Device & System for Rwanda Coffee Farmers and Co-op Members who will use **"Minimalist"** Internet connectivity.

TITLE: Research/Designer Morphological Matrix Communication tool.

Researcher's Notes/Comments

DATE LAST EDITED BY RESEARCHERS: May 9, 2007

1,2) Farmer and Co-op Member Communication Frequency and Distance

365x per year:	Oxygen Gear (by consumables). Agronomists (none by consumables). Export managers (none by consumables). Other Farmers (none by consumables).
52x per year:	Banks (Kigali), Banks (Rural), New Coffee Federation (Kigali), Local Co-op Administration (None by Consumables), Ministry of Defense (Kigali), PEARL Project Headquarters (Kigali).
12x per year:	Buyers (Kigali), Buyers (International), National Coffee Agency (Kigali).
4x per year:	International Coffee Buyers (Innovation), Ministry in-charge of Co-ops (Kigali), Rwanda & Ongoing training activities.
1x per year:	National Research Institute (Butare).

3) Types of Coffee Co-ops

The *Sub-POP cooperative type* resides in a locale with a substantial business district. There is enough demand to support a cooperative-owned cybercafé and the installing of capacity to local schools, health centers, and government offices. They require fairly high bandwidth (at least 384 Kbps) and a WLAN network to share Internet connectivity with neighboring entities.

The *Teleworker cooperative type* operates a cybercafé, but does not resell bandwidth to local entities. 256 Kbps of bandwidth through the WWAN is sufficient.

The *Rich cooperative type* desires high quality connectivity (at least 128 Kbps), but does not run a cybercafé or resell to local entities.

The *Minimalist cooperative type* resides in an isolated locale and requires minimal connectivity for e-mail use (48 Kbps).

6) Based on observation as well as a casual interview with our translator none of the participants we met with spoke fluent English, and in fact probably spoke only Kinyarwanda fluently, although some may have spoken some French. The language issue, although not explored in this study, may be a significant barrier to the successful use of ICTs in Rwanda.

11,12,13,15) Farmer & Co-op Member Familiarity with Communication Methods

PDA	0% Familiarity
Laptop	0% Familiarity
Desktop Computer	0% Familiarity
Cell Phone	80% Familiarity
Beeper	0% Familiarity
Fax	0% Familiarity
Phone	80% Familiarity
Letter	50% Familiarity
Face to Face	100% Familiarity

22) Participants mentioned that although face to face communication is "easier to use" it's not always "easier". For instance many mentioned that in order for them to meet face to face with someone, often they had to walk for many hours. For example, we heard the following story recounted:

"After hours of travel the farmer or co-op member would finally reach an assembly point where they were expecting to meet face to face with another stakeholder. However, upon arrival, the farmer would come to find the person they were attending to meet was not there. While waiting for the other person to come, they would question to themselves, 'Are they not coming at all? Are they just a little bit late? Have they already been here waiting and have decided to leave? Have they just stopped out for a quick bite to eat? Have they forgotten?' Have I wasted my time walking all the way over here?"

This process could often take a whole day, with the possibility of a missed meeting quite real. However, problems such as this could be avoided if only stakeholders could communicate real time. After evaluating the frequency of these types of meetings, and considering the importance of maintaining the personal relationships between stakeholders, future ICTs would be a remarkable and frequent benefit to all stakeholders.

FUNCTION	PHASES	(shows what a product should have or be) PARAMETERS		(shows alternative ideas to parameter) PARAMETER OPTIONS A	B	C	D	E	F	G	UNKNOWN
HUMAN FUNCTION	economic - social	Frequency of communication per year.	* 1	1x per year	2x per year	4x per year	12x per year	52x per year	365x per year		X
		Greatest distance of communication.	* 2	local farmer & co-op nbr	Nearby communities	Kigale	Butari	International			X
		Typical number of users per device.	3	1 per device	Shared betwn 2-10 people	Shared betwn 10-30 people	Shared with all of community.				X
		Method identifing device ownership	4	none	add name	personalize/ decorate					X
		Acquisition of communication device by user.	5	borrow from friend.	Pay per use	rent/lease	purchase	In public domain			X
		Primary language	* 6	English	French	Kinyarwanda	Symbols/Icos				X
			7								
			8								
			9								
			10								
	aesthetic - cultural	Level of user familiarity with communication device FORM aesthetic.	** 11	NO familiarity	Only heard of, Never seen.	Seen before, infrequently.	Seen, friends w/similar form	Have device with this form.	Grew up with this form.		X
		Level of user familiarity with communication device over all STYLE aesthetic.	** 12	NO familiarity	Only heard of, Never seen.	Seen before, infrequently.	Seen, friends w/similar style	Have device with this style.	Grew up with this style.		X
		Level of user familiarity with communication device MATERIAL aesthetic.	** 13	NO familiarity	Only heard of, Never seen.	Seen before, infrequently.	Seen, friends w/similar mtrl.	Have device with this mtrl.	Grew up with this material.		X
		Level of *preceived* value.	14	Cheap/Free	Low value.	medium value	High value	Priceless			X
		Communication device platform most similar to:	* 15	Phone	Fax	Peeper/pager	Cell phone	Desktop Computer	Laptop Computer	PDA	X
			16								
			17								
			18								
			19								
			20								
	practical - physiological	Device primarily enables user for what communication (may be more than 1 but what is primary)	21	printed doc.	voice via device.	screen text or graphic	Video display				
		Reasonable time frame for communication exchange.	* 22	instant	>12 hours.	12hrs - 1 day	2-7 days	1-4 weeks	1-4 month		X
		Level of user familiarity with communication device. (product function, how to use)	23	NO familiarity	Only heard of, Never seen.	Seen before, never used	Used before, not expert.	Used before, very familiar.	Used before, expert user.		X
		Primary communication method (input) from user to communication divice.	24	typed text	screen icon selection	Audio input	control buttons	video capture			
		Primary communication method (output) from communication device to user.	25	displayed text	displayed graphics/icons	audio output	video/animation	video display			
			26								
			27								
			28								
			29								
			30								

Designer's Notes/Comments/Questions

DATE LAST EDITED BY DESIGNERS: Aug 14, 2006

2) I need a map of Rwanda to identify the distances.
4) Is property taken violent? (by who? Neighbors? or outsiders?
6) It may be better to have multiple options so that this product can be used in many countries.

11, 12, 13) It is necessary that the user of an object have prior information about the object in question, otherwise they may refuse to buy/selection it because it is too new and strange conception. The association between user and object depends upon the user's past experience and their habits.

14) Would it be important for this to become a "Status symbol" by the user? Or could it cause problems?

22) It would be acceptable if the response time was between 0-2 hours. If that makes any difference in the reduction of technology costs.
23) There could be a training animation included in the interface design.

* Indicates there is information in the "Researcher's Notes/Comments" column.

* Indicates there is information in the "Designer's Notes/ Comments/Questions" column.

RESEARCHER / FIRM: K. Caine, W. Hargrove, M. Sun

DESIGNER / FIRM: Test Study

PROJECT: Communication Device & System for Rwanda Coffee Farmers and Co-op Members who will use "Minimalist" Internet connectivity.

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Researcher's Notes/Comments

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31) Cellular-based Wireless Wide-area network (WWAN) deployments such as GPRS, CDMA2000 1x, and CDMA2000 EVDO are the preferred solutions if enough aggregate demand exists within the coverage area, otherwise fixed-link WWAN deployments utilizing WiFi and WiMAX are more viable when specific locales must be reached and regional demand is uncertain.

32) (also see Notes in Human Function economic social)
VoIP - Voice over Internet Protocol (i.e. Skype)

Designer's Notes/Comments/Questions

DATE LAST EDITED BY DESIGNERS: Aug 14, 2006

41) or "no accessories" if this is going to be mass and typically available for public use. Could be marked in such a way that nobody would want to keep it for too long.

FUNCTION	PHASES	PARAMETERS (shows what a product should have or be)		PARAMETER OPTIONS (shows alternative ideas to parameter) A	B	C	D	E	F	G	UNKNOWN
TECHNICAL FUNCTION	direct technical interaction (interaction of part of artifact to another part)	Wireless Network Technology *	31	WiFi (802.1)	pre-WiMAX	Wifi(802.1) & pre-WiMAX	VSAT	CDMA2000 1x	CDMA2000 EVDO	CDMA2000 1x & CDMA2000 EVDO	
		Device's most advanced and frequently used communication technology. *	32	Land line telephone	e-mail	low bandwidth internet access	VoIP	rich web content	Streaming video		
		User communication device power supply	33	Human power	Solar Pwr	Battery Pwr & AC/DC Adapter	Multiple combinations				
		User communication device basic housing material.	34	Polycarbonate	ABS	aluminum	bio mass	steel	wood	plant fiber	
			35								
			36								
			37								
			38								
			39								
			40								
	indirect technical interaction (interaction of part to non-human environment)	Decorative accessories compatibility	41	only after market items	only hand made items	Only in house production items	all possible				X
		Method of personalization	42	clear window/ pouch on device	hook for lanyard	surface for decorating	none				X
		Typical device in use environment	43	Outdoors	Indoors	both outdoor and indoor					
			44								
			45								
			46								
			47								
			48								
			49								
			50								

* Indicates there is information in the "Researcher's Notes/Comments" column.

* Indicates there is information in the "Designer's Notes/ Comments/Questions" column.

RESEARCHER / FIRM: K. Caine. W. Hargrove, M. Sun

DESIGNER / FIRM: Test Study

PROJECT: Communication Device & System for Rwanda Coffee Farmers and Co-op Members who will use **"Minimalist"** Internet connectivity.

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51, 52) Operating expenses such as human resources and bandwidth dominate the overall costs of these networks (bandwidth tariffs generally rise exponentially as bandwidth requirements are increased, but rate display great variability across technologies. This is a result of the complex set of revenue and external funding streams telecoms receive that subsidize certain technologies' deployments in differing ways.

53) Many area countries are within reach of existing base stations. Cellular base stations have a coverage radius of roughly 30 km. The liberal regulatory environment ofRwandaalso allows several technologies to be used (ex. connecting the cooperatives—voice-over-IP (VoIP) is permitted and the 2.4 GHz frequency spectrum is unlicensed. These factors bring optimism that innovative, cost-effective solutions can be found to network the cooperatives.

54) Telecoms/ISP:
MTN-Rwandacell is the dominant mobile telecommunications operator with a GSM/GPRS network covering an estimated 70% ofRwanda.
Artel has been addressing rural telephony through their satellite-based VSAT deployments, but performance and penetration remains low.
Terracom, a new telecom and ISP is aggressively implementing a fiber/hertzfi network and deploying CDMA2000 coverage. Their acquisition of the incumbent government telecommunications provider, Rwandatel, means they operate much of the existing wired telecommunications infrastructure (Nsengiyumva and Stork 2005).

61) For cellular operators, the rough cost of deploying a new base station (tower and equipment) exceeds US $100K. In order for the operator to offer their advertised subscription prices, enough latent demand would have to exist in that locale to offset the large capital cost. Those rural regions are tracked by uncertainty of demand and provisioning of new base stations can be a risky endeavor.

FUNCTION	PHASES	(shows what a product should have or be) PARAMETERS		(shows alternative ideas to parameter) PARAMETER OPTIONS A	B	C	D	E	F	G	UNKNOWN
PRODUCTION FUNCTION	planning	Government tariff or subsidy policy for technology.	* 51	○ High tariff	○ Low tariff	○ No policy	○ Low subsidy	● High subsidy			X
		Donor organization financial support for technology.	* 52	○ Zero funding	○ Light funding	● Heavy funding					X
		Within range of existing cell tower	* 53	● Yes	○ No						X
		Primary point of user device distribution (distr)	54	○ distr thru gov. agency	● thru private businesses.	○ thru donor agency.					X
		Rwandan telecoms/ISPs available to provide services.	* 55	● MTN-Rwandacell	○ Artel	○ Terracom					
			56								
			57								
			58								
			59								
			60								
	Manufacturing	Number of towers needed to be built	* 61	○ none	● 1	○ 2	○ 3	○ 4			
		Tower construction time frame.	62	○ one day	○ one week	● one month	○ two months				X
		Location of communication device manufacturing.	63	● Africa	○ Asia	○ Europe	○ North America	○ South America	○ China	○ India	X
		Location of communication device assembly.	64	● Africa	○ Asia	○ Europe	○ North America	○ South America	○ China	○ India	X
		Manf. cost of communication device.	65	○ Free. Re-use parts/ User assembles.	○ $1.00-$5.00	○ $5.00-$10.00	● $10 - $25	○ $25 - $50	○ $50 - $75	○ $75 - $100	
			66								
			67								
			68								
			69								
			70								

Designer's Notes/Comments/Questions

DATE LAST EDITED BY DESIGNERS: Aug 14, 2006

65) perhaps more research can be done on the $100.00 laptop computer that was developed?

* Indicates there is information in the "Researcher's Notes/Comments" column.

* Indicates there is information in the "Designer's Notes/ Comments/Questions" column.

Morphological Matrix Use Questionnaire

On a scale from 1-6 (1 being the least, 6 being the most)

1. How familiar are you with the use of a morphological matrix?

N/A ○ *never heard of it.* ○1 ○2 ○3 ○4 ○5 ○6 *extremely familiar*

2. How helpful did you find the additional "Researcher's Notes/Comments" in making a decision?

N/A ○ *not helpful* ○1 ○2 ○3 ○4 ○5 ○6 *most helpful*

3. Even though you have not taken part in the development of the options/concepts, how comfortable are you in making decisions using this morphological matrix?

N/A ○ *extremely uncomfortable* ○1 ○2 ○3 ○4 ○5 ○6 *extremely comfortable*

4. Did you add any "Designer's Notes/Comments" to the parameters?

N/A ○ *YES* ○ *NO* *If no, why not:* _____

5. How useful do you think your additional information will be to other members (researchers, designers, engineers, and marketing) of the development team?

N/A ○ *not helpful* ○1 ○2 ○3 ○4 ○5 ○6 *most helpful*

6. What type of information would you like to add to the "Designer's Notes/Comments/Questions" column? (select all that may apply)

N/A ○

- ☐ *More detailed description of selection.*
- ☐ *Comments on selection criteria or condition.*
- ☐ *Request for more research.*
- ☐ *Questioning of the provided research data.*
- ☐ *Detailed images of solutions.*
- ☐ *Other:* _____
- ☐ *Other:* _____
- ☐ *Other:* _____

7. What else could be added or remove to make this chart be helpful in the development process, particularly between researchers and concept developers?

N/A ○

APPENDIX B:

STUDY DATA

Human Function Morphological Matrix Parameter Option and Designer Input Data (page 1 of 3)

ID#	1	2	3	4	5	6	11	12	13	14	15	21	22	23	24	25	Designer's Input for Social-Economic	Designer's Input for Aesthetic-Cultural	Designer's Input for Practical-Physiological
hoy	6	5	2	3	1	3	3	2	3	6	7	2	1	3	3	3	1) In order to maintain a good business presence, a company must have continual contact with the market, and the people that they are doing business with. This is needed in order to set prices competitively, understand trends, take advantage of opportunities, and establish good business connections. 1)This question should be "calls per week" and "calls per day". 2) this question is obvious.	11, 12, 13) All of this depends on how the people are introduced to the products. They must be made to be familiar with the device before they ever encounter it. So, how well has this product been introduced to the market. Precieved value will come almost entirely from functionality	23) the user must be shown the device, and have already used one before they have the opportunity to buy one 24 25) Being able to talk to a business contact is priceless
atil	6	3	2	1	5	3	4	4	5	3	4	2	1	4	2	2			
datacl	4	5	3	2	3	3	4	2	3	3	5	3	2	3	1	1	for question 3 - trying to be economical and practical for 5. --I need to know who would be providing money for rent/lease	11. will someone be able to teach the users? 14. the device should not be very cheap, but not too expensive or unique that its novelty provokes more attention than its function	22. i want to say instant, but let's be realistic...if these people aren't used to using this type of communication are they really going to be on stand-by for the device? 23. assuming there is a tutorial
9	6	5	2	2	5	4	3	2	1	3	4	3	1	3	2	2			
other6666	5	5	4	2	5	4	3	2	4	3	2	1	3	3	1	2	50x per year at the very least. This should be a reliable source of communication internationally.		% of the farmers (and stakeholders) ability to read and write? Translate Typed text b/c 90% communicate through letters which means most stakeholders can write.
ess	5	5	3	1	5	3	4	4	4	4	4	4	3	3	4	2	3, 4, 5) I want to know how many are involved at the "community" level and if there is a a common (public) meeting place.		21) Is it safe to assume that the users are all literate? 32) Where is 32?
data1666	5	5	3	2	3	4	3	2	4	4	4	3	2	3	2	2	1) The Co-ops should be able to at least communicate through the means of an internet device to areas that are not necessarily easily accessible by other forms of communication. What are the limits of these other forms of communication in more local areas in achieving needed interaction in a timely manner? 2) How far out are the nearby communities and again, how easy is it to interact by other means? 3) Exactly how often and for how long use of the device is needed by the individual user seems to be.	6) Depending on the actual device, it would seem to be more quickly understandable to use pictographs with which to associate the device's functionality to recognizable keywords into the appropriate language. As far as FORM and STYLE I'm not sure what they are judging against besides basic devices they are familiar with. What other culture cues would influence this?	
research4 346	3	5	2	2	2	3	4	2	3	3	4	3	4	4	1	1	The frequency of communication per year refers to different alternative answers, but they are not clear about what is most commonly used.		
dataaw	5	5	3	2	5	3	2	6	4	4	4	3	1	3	2	2	1. I think that having a 3rd world culture depending on using a specific communication device daily would be more disruptive than helping --especially if there was any technical difficulty 6. why not have it in a language they can understand? this would require a translation of the data at some point, but it does not need to be on the user's end		24. why is "written text or symbols" not an option? 25. it seems that the best option to me would be some kind of electronic file that was readable by a program, such as an excel file
data6677	6	5	4	1	4	3	3	2	5	3	6	3	1	3	4	2	Is identifying ownership common in Rwanda? In the US, I don't see question 4 as an important parameter.	The difference between style and form should be clarified. It is easy to confuse the two.	Questions 24 and 25 seem like good questions regarding different communicating cultures.
data123	6	5	2	2	3	4	3	2	2	4	7	1	1	2	2	2	Notes from study participant Holly Fay:		
oil	6	5	2	3	3	3	4	2	5	4	4	2	2	4	3	3	I started by reading the page before this and then reading all the green Researcher's Notes along with the parameters and their options. Then I tried to approach each parameter without thinking of my previous answers, but it is difficult to separate the parameters from each other. It is also difficult to think about the best solution for each parameter without my preconceived notion of what's best.		Note from study participant Holly Fay: 22) Is the second option supposed to be <12.? That's what I want to select.
rent	5	5	2	1	5	4	3	2	3	2	4	2	1	3	3	3			

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eic	5	5	2	1	2	4	6	5	6	4	4	3	1	3	2	2	1) For cost considerations, contact with world market should be establish at minimum once a week. Daily would be ideal if cost was not a factor. 3) If international market business is conducted once a week, one device could be shared among co-ops. 5) Symbols/icons remove the language barrier, but given a strong consideration to cultural custom differences when selecting and designing icons.		23) It would be beneficial to introduce new technology to a culture that is easy to learn how to use, similar to already familiar items.
241	6	4	2	1	4	3	3	4	5	3	1	3	2	4	1	1	6) Is it possible to translate between the different languages through the device instantly depending on the receiver? Perhaps pre-written texts to choose from that wouldn't need to be translated but change automatically?		24, 25) Instead of a screen icon selection, perhaps this could be a selection of pre-written text.
aso	5	3	2	1	2	4	6	2	4	3	2	1	2	3	4	2	All my choices are represent my thoughts on what is a realistic option for Rwanda as a poor country and what is necessary to provide minimalistic internet co nnectivity.	4. I believe device ownership is less of a problem because they should be shared between a few users. Even as students we sometimes share connectivity devices as groups. Adding a name or personalizing the device seems to be an unnecessary cost. If all ownership labels were removed the money saved might equate to an additional device.	21, Need to find out what the needs of the comsumer are: do they need to print? Does it need to be portable? What energy sources are most accessible? 22. What is the urgency of coffee communication? 1-25, What KIND of communication is happening? Directions, Numbers, logistics?
fia E	6	5	2	1	3	4	4	4	3	3	6	3	2	4	4	1	All my choices are represent my thoughts on what is a realistic option for Rwanda as a poor country and what is necessary to provide minimalistic internet co nnectivity.	4. I believe device ownership is less of a problem because they should be shared between a few users. Even as students we sometimes share connectivity devices as groups. Adding a name or personalizing the device seems to be an unnecessary cost. If all ownership labels were removed the money saved might equate to an additional device.	21, Need to find out what the needs of the comsumer are: do they need to print? Does it need to be portable? What energy sources are most accessible? 22. What is the urgency of coffee communication? 1-25, What KIND of communication is happening? Directions, Numbers, logistics?
data4102	6	5	2	2	5	4	3	2	1	3	4	3	1	3	2	2			
917	6	5	2	2	4	3	5	1	1	1	1	2	1	1	3	3	3) This begs a larger question.....How are Co-ops operated. Aside from answering the obvious question of how many people from the Co-ops will be needing to communicate we will also need to now to what extent each of the individuals/workers will need to communicate. Will one person be ordering farming supplies form the local area and anther be taking orders and confirming shipments internationally? 6) Obviously one language will not suffice. International orders will need to be in a common language or some means of interpretation will be necessary. I would think international business would be done through e-mail or other computerised data entry system and local communication would be in there native tongue(cell phones/sat phones).	11,12,13) By form I assume what type of product i.e. cell phone, computer, fax..... In reference to style I don't think the color or shape of buttons will effect the user.....This allows for purchasing the lowest cost items since all that needs to be considered is the form. In reference to Material the same logic as style applies. It does not matter if the phone is an aluminum covered Razor or a plastic phone. Once again.....get the least expensive option no matter the material. 14) Will a Co-op worker refuse to use an item based on perceived value?? 15) Once again we need to know how these Co-ops work. Cell phone for manager to access common used supply chain, Fax/Desktop computer for order entry, accounts payable,etc.....	21) Most applicable to all but more than one communication method will inevitably be needed. Also need printed doc. (fax) at least for international dealing, prefer computer 22) Instant for daily needs, 12-2days for order entry and paper work. 23) its work ....they will learn it or go out of business 24) same issue of job functions..... audio most common but typing will be necessary 25) same issue of job functions..... audio most common but text will be necessary
1217	4	4	3	1	4	4	4	2	4	4	7	3	2	3	2	2	3,5) The number of users per device should vary depending on the location and connectivity of the users. It may be more efficient to share a device between an entire community in the Minmalist Cooperative Type. The acquisition of a device should also vary depending on location and type. Modes of acquisition such as Pay per use and Borrow from friend may not be available in the more rural areas. The purchase of at least one device per community may be the only option for these areas.	6) The primary language should be symbols/icons to promote easier international communication. There should be a secondary supporting language of Kinyarwanda.	11,12,13) If this is a device unique and specific for this function, the prior familiarity may be less important if some form of training session can be held for the groups involved.
906	4	5	2	1	5	4	3	2	3	4	4	3	2	5	4	2			
668	6	5	2	2	5	1	4	5	5	3	1	3	1	3	1	1			
439	5	4	2	3	5	4	5	2	4	3	4	3	2	4	4	2			
311	5	5	2	2	2	4	5	4	3	4		3	1	4	2	2	11 - At first I was a bit confused by the wording of this question, but I figured it out relativey quickly. I think that it's important for the form of the device to be very familiar to the user so that it will be easy for them to use the device. That way, the user is more likely to use the device.		
240	5	2	2	2	3	3	5	5	3	4	4	2	1	4	3	3			
228	6	5	2	1	5	3	4	4	1	3	5	2	1	5	2	2			

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124	6	5	2	2	2	4	4	2	3	3	4	2	1	3	3	3				
107	5	5	2	2	3	4	4	2	4	4	4	2	1	4	2	2	1) With easier ways of communication, frequency might increase 5) lease to buy? 6) symbols make it easier for even the illiterate to use, however symbols might be difficult to interpret especially with unfamiliar functions; combination of voice (Kinyarwanda or French) and icons best		
424	4	5			1	3	3	5	4	4	3	4	3	3	4	4	1			
239	6	5	2	2	3	3	5	5	5	4	6	2	1	3	4	2	4) maybe a receipt 6) Use of more than one language as well as symbols and icons my be best solution		15) Do not entirely understand the parameter; Chose device type thought most appropriate to project	
630	6	2	2	1	3	3	3	2	5	4	4	2	1	2	3	3				
1261	4	5	2	2	5	3	3	2	3	3	1	2	1	3	3	3				
323	6	5	3	2	5	4	2	1	1	3	1	2	2	2	3	2			11,12,13) it ay be necessary tounderstand form to undstatnd the imporantcs of use. so that it can be sued properly. THe sunderstanding of form . How ever form is more imporatant than the style and aethetics.	
318	6	5	1	1	2	3	5	5	5	3	4	2	1	4	3	3	I assume that im suppose to pick a devise and answer based around that devise? Im gonna go with cell phone #4 Why not have it registered? Proof of purchase (a receipt)? The honor system?			
119	4	3	2	1	3	3	4	2	3	2	5	3	2	4	4	1	All my choices are represent my thoughts on what is a realistic option for Rwanda as a poor country and what is necessary to provide minimalistic internet connectivity.	4. I believe device ownership is less of a problem because they should be shared between a few users. Even as students we sometimes share connectivity devices as groups. Adding a name or personalizing the device seems to be an unnecessary cost. If all ownership labels were removed the money saved might equate to an additional device.	24) Instead of having a full fledged keyboard, which would increase costs, I believe having general question tick boxes (much like the ones used on this form) could be used. Maybe a set of frequently used question with yes/no answers would increase the a mount of users who could use the device.	
N.7	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0				
N.6	17	0	0	0	0	0	2	1	1	0	3	0	0	0	0	0				
N.5	11	27	0	0	13	0	7	5	8	1	3	0	0	2	0	0				
N.4	4	1	0	0	0	6	5	3	3	6	8	0	0	7	5	0				
N.3	1	3	6	3	11	18	12	0	11	18	0	18	3	16	10	9				
N.2	0	2	25	17	6	0	2	20	1	2	2	14	11	2	12	19				
N.1	0	0	1	15	1	1	0	2	5	1	5	2	20	2	5	7				

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31	32	33	34	41	42	43	Designer's Input for Direct Technical Function	Designer's Input for Indirect Technical Function
1	1			4	3	3	All of these questions require substantial research into the fields of cost, availability, reliability, politics, construction issues and expansion possibilities.	This device should be rugged (sometimes, the indoors are just as bad as outdoors. Almost all personalizations will be hand made.
7	3	4	2	4	2	3		
2	6	4			4	2	31. i want to answer that the more viable be used, however i dont know the difference between (a) (b) and (c) is 33. what makes sense here? what area are we talking about? what is possible/probable? 34. let's ask the engineer. what is most reasonable/realistic? what is going to be most cost	41. why do we care about decoration? i want to design for the sole purpose of making money easier and more frequent
1	5	4	2	1	1	3		
6	3	4	2	4	4	2		
6	3	3	1	1	4	2		
3		4	2	4	2	3	31) Further definition of the particular technologies would be helpful here in determining the best solution to manage the coverage in different areas. 32) Multi-combos of power solutions would be a good idea here b/c of the possible wide range of factors that may limit access to sufficient power supply to recharge a device.	
5	4	3	3	4	4	3		
5	4	4	1	1	2	3	31, 32. i need more information about this mumbo jumbo. i am not informed enough about the existing infrastructure 34. need more info about the positives and negatives of each material selection	42. probably in rwanda, the indoors is not so much different from the outdoors in many cases
3	3	2	4	4	3	3	I don't understand anything about "wireless" network technology. The capabilities should be explained in laymen's terms unless the designer and researcher are already know to be tech savvy.	Does personalization come up often? I don't think of that as an important parameter for US culture.
	2	3	1	4	4	3	Does anyone of the wireless technology options have a significant advantage over another. Or, does one option benefit the user more than another?	
1	2	3	2	4	3	3		
7	1	2	2	4	4	3	Is the date on the researcher's box supposed to be 2007?	It should be anticipated that the device will be exposed to extremely harsh conditions. Decorative accessories and personalization might have dire consequences. Friction between the Hutus and the Tutsis is still a concern in the wake of the Rwandan civil war in 1990. Decorative elements might be used to identify and ostracize individuals or ethnic groups.

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1 2 4 1 1 2 3	33) Combination of primary solar power with back-up battery, easy to replace (AA or AAA)	
7 1 3 2 4 4 2	34) I am not sure which material would be the most suitable for the device.	
3 2 4 2 4 3 2	31. who needs to be reached, is it always the same location or is it more unpredictible?	42. Does this object need personalizing for theft prevention, or because each gadget contains person-specific data? If all devices are on the same network with the same info, no personization is needed. 43. Does the device need to travel outdoors?
2 3 2 4 4 1 3	31. who needs to be reached, is it always the same location or is it more unpredictible?	42. Does this object need personalizing for theft prevention, or because each gadget contains person-specific data? If all devices are on the same network with the same info, no personization is needed. 43. Does the device need to travel outdoors?
1 5 4 2 1 1 3		
1 2 3 1 4 3	31) Ultimately both voice and data must be accommodated. Method will depend on scale....how many farmer , in how large an area. 32) Voice and Data in what ever form. Cheapest, most scalable, easiest to deploy	41) E - NONE
1 3 3 2 1 4 3		41,42) Personalization allowances are not important as product will be shared among 10-30 people.
3 6 4 3 1 4 3		
7 1 4 2 1 1 3	What local resources are most advantageous to facilitate housing material options?	Could there be more options for personalization or os it really that important? What further details or options could be added to give me a better idea of the environment in which this device would be used? (ex. on the corner of street, on wall inside hut, etc.)
3 4 4 6 2 3 3		
1 4 4 2 1 1 3		
7 3 4 1 4 1 3		
7 4 4 1 4 4 3		
5 4 4 1 4 2 3	What is the difference between CDMA2000 1x, CDMA2000 EVDO, etc?	

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4	4	4	1	4	4	2	31) Need more information regarding difficulty and expense to initiate, availability		
1	3	2	2	3	4	1			
2	2	3	2	4	2	3	34) Which inorganic materials are the cheapest/most durable/etc..? Are these materials able to be manufactured in Africa? Are the organic materials long-lasting and durable?		
3	4	4	1	4	2	3			
	4	4	6	1	4	2	31) I can't answer this question to the best of my ability because I still cannot differentiate among the options, more information is needed.	Are Rwanda's citizens Artistic people?	
1	1	2	4	1	3	3			
3	1	3	1	4	4	3	31) I hate acronyms		
1	3	3	2	4	2	3	31) Depending on what types of connection options are already present, I think the most realistically available technology should be used, according to the note that would be WiFI since the area of coverage would not have enough users to use the system efficiently.		
6	0	0	0	0	0	0			
2	2	0	2	0	0	0			
3	2	0	0	0	0	0			
1	7	10	1	8	6	0			
7	9	10	2	1	6	27			
3	6	5	15	1	8	7			
11	6	0	11	11	6	1			

Prodcution Function Morphological Matrix Parameter Option and Designer Input Data (page 1 of 3)

51	52	53	54	55	61	62	63	64	65	Designer's Input for Planning	Designer's Input for Manufacturing
5	3	1	3						1	51 52) Time should be spent getting grants and other funding options, but these options are highly political. 53) this product should be used within range of cell towers if they use cell towers	61) Can the population support the towers? Are the businesses located near exsisting towers? Does the device need cell towers? 62)How long does it take to build a tower? How much man power is avalible? government regulations??
2	2	1	3	1	1	3	2	2	2		
4	3	1		3	1		2	2	4	53. maybe exceptions are made for high "traffic" farm or business areas that are not close to tower...preferably, towers are already existent and in proximity 54. who has the most interest? the most to gain? who can we Sell on the idea of helping us (the farmers)?	
1	2	1	2	3	2	3	7	2	5		
2	3	1	1		4	4	3	5	6		
4	2	1	3	1	1	1	6	1	5		
4	2	1	1	1	2	3	6	6	3		
2	2	1	1	3	3	4	2	1	4		How much can the farmer or co-op afford, according to their salary?
3	2	1	2	1	2	4	2	2	3	55. would it be possible for it to work with all of them?	
5	2	1	3	1	4	4	1	1	2	It seems like to decide cost issues there would have to more in depth understanding of what is possible to begin with. For example, can you ensure that there will be a subsidy offered or which company is willing to partner with you for services?	How can I be deciding the time frame without an understanding of the consequences? How do we know a tower can built in a day?? Of course shorter is better, but I'm guessing there are cost issues.
3	2	1	2	3	3	3	2	2	5		Do the people of Africa or Rwanda have the capability of manufacturing or assembling such a product?
3	2	1	2	1	1	2	2	2	3		Note from study participant Holly Fay: 61) The researcher's note does not help me decide what number of towers are needed-- has mention of demand, coverage, amount of rural areas. I feel ill-equipped to select any of the manufacturing options. I suppose
4	2	1	1	3	5	2	2	2	3	I think there should be an option to allow any combination of the three Telecoms/ISP to work together. Specifically, I think that if the device needs to work with both MTN-Rwandacell and Terracom. The success of the device would be more likely if it utilized both the substantial wired infrastructure already present and the wireless infrastructure that has 70% penetration.	China still has a slight reputation for producing electronic components that are less reliable than those produced in South Korea and other countries in the region.

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4	2	1	2	1	1	3	1	1	3		63) Manufacturing in Africa would escape import taxes and difficulties, save transport time and cost, and provide more jobs in the region.
2	2	2	3	3	1				4	51 -55) Many of these parameters I was unsure about. I don't have enough information to come up with a definite solution to these concerns.	62, 63) I left these two blank because I was unsure of which would be the best solution to build the device for cheap but still maintain quality
2	2	1	2	1	2	3	6	7	3	54. What is the Rwandan government stability like?	
3	3	1	2	1	1	3	4	4	4	54. What is the Rwandan government stability like?	
1	2	1	2	3	2	3	7	2	5		
2	2	2	2	3	1	3	6	6		52) Deals with communication companies for equipment is there service is used exclusively. 53) other methods of communicating exist. 55) Need more than voice	61) No way to answer this with out mote specific information regarding geography and tower locations 63) Need cost analysis as well as defective reports and communication disruption reports 64) Same as origin of communication device...presumably 65) Cannot answer need more research
2	2	1	2	2	3	3	2	2	2	53) In some cases, there may be a need for a new cell tower.	61) This number depends on the need
2	2	1	1	1	3	3	1	1	5		
1	2	1	1	3	2	3	6	1	5		
2	2	1	3	1		3	6	6	3	What options exist for donor organizations that would be willing to fund?	What other factors need to be considered if device is imported from other continents? -shipping / importing costs
3	2	1	3	3	1	3	2	1	2		
4	2	1	1	2	3	4	1	6	2		
2	3	1	2	3	5	4	6	1	1		#61: Current average # of towers within certain parameters unknown.
5	3	1	2	1	1	3	2	2	1		

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2	2	1	1	3	4	2	1	1	4			
4	3	1	1	1	5	4	1	1	2			
4	3	2	3	3	3	3	6	6	3	51) limited knowledge of the subject		
4	2	1	1	3	2	3	1	1	6			
2	2	1	2	1	3	3	6	6	4			
2	2	1	1	1	3	3	2	1	5			
3	2	1	2	1	2	2	2	2	3	#51 Eenie, Meenie, Miney, Moe need more info on how it varies with each technology #52 can you get financial support or is that wishful thinking?	# 61 how big is the area? how many towers are already in the area? # 62 how long does it take to build a tower? # 63 Is Rwanda not capable of manufacturing anything? # 64 Is Rwanda not capable of assembling anything? # 65 how much does it cost to make a cell phone?	
2	2	1	3	1	3	4	6	6	5			
0	0	0	0	0	0	0	2	1	0			
0	0	0	0	0	0	0	10	7	2			
3	0	0	0	0	3	0	0	1	8			
4	0	0	0	0	1	4	0	0	2			
6	8	0	9	14	9	19	1	0	9			
14	27	3	14	2	8	4	12	11	6			
3	0	32	11	17	10	1	7	12	3			

Questionnaire Data (page 1 of 3)

Q1	Q2	Q3	Q4	Q5	What could be added/removed to improve this chart	Q7	More detailed description	Comments on selection	More research	Questioning of data	Detailed images	Other	Other	Other	
1	5	1	1	6	This chart could be very useful in making decisions if enough information was included. I could not make many of he decisions due to the fact that there was too much information lacking.		1	0	1	0	0	0	0	0	
2	5	2	No	4	I think it was fairly well done as is. However, I would have preferred more research beforehand, combined with the abstract, because I just attributed my confusion to my lack of familiarity with the topic. I feel if I had more to read, got more in depth and more involved with the research as a whole, I would have felt more confident with my decisions. This would definitely be a "feedback" result, and would gleefully await more information/research.		1	1	0	0	0	0	0	0	Felt my confusion was due to the lack of familiarity with both the format and topic
2	5	3	1	5	I'm not sure. as this was my first time filling one out I felt it was detailed. but i have nothing to compare the chart too.		1	0	0	0	0	0	0	0	
1	5	3	No	3	perhaps a historical account of any similar endeavors that have succeeded or failed.		0	0	0	1	0	0	0	0	
2	5	2	1	5		Yes	1	0	1	0	0	0	0	0	
2	6	4	1	4	Perhaps researchers' recommendations and some optional way to show how strongly the designer feels about their decision (especially in situations where more information is needed).		0	1	1	0	0	0	0	0	
2	3	3	1	2			1	0	1	0	0	0	0	0	
5	5	4	1	5		Yes	0	0	1	0	0	0	0	0	
1	3	2	1	3		Yes	1	1	1	1	0	0	0	0	
2	5	4	1	4	A way to put "I'm unsure" or "I'm between these 2 choices." It seems so definitive to fill in a bubble, I feel bad that I have uncertainties about my choices!		1	0	1	0	0	0	0	0	
2	2	2	1	1	I think a more informative introduction would be helpful. Even thought you might have went over what the product is in the beginning, it would be nice to have a reminder of what it is exactly we are trying to develop. I think because designers naturally respond to images and graphics, some sort of imagery or better organization of the questions and researcher's information would be extremely helpful.		0	0	1	1	1	0	0	0	
4	4	2	1	3	Reproducing the charts with different objectives for each reproduction may help with comparing all the connections between options and solutions. For example, one set of charts could have an emphasis on cost-effectiveness, another on quality of communication, another on long-term sustainability. As the designer I feel I'm juggling many variables to select the best solution for a parameter, but it may result in an over-all solution that's tugged in 70 different directions.		0	1	1	0	0	0	0	0	
2	6	5	1	4	Additional information is always better. The more information an individual has at their disposal, the better equipped they are to make a decision.		1	1	1	0	0	0	0	0	

Questionnaire Data (page 2 of 3)

																					A little more background and general description of the goal of the end product.
4	5	4	1	4			Yes	1	0	0	0	1	1	0	0						
5	6	4	1	4	Although information is provided about the options in the researcher's box, perhaps adding resources or links regarding the information may be helpful. Also when the researcher responds to the concept developer, some sort of reference to their question may be needed to explain why additional information was added. Perhaps numbering the Concept Developer's boxes in order to easily answer concerns and questions. Overall I felt as the designer that I was more informed in my decisions because of the researcher's			1	1	0	0	1	0	0	0						
2	5	5	No	NA	- Maybe a map to show the geographical locations mentioned. -Possibly better hints to look at researcher notes... I didn't always see the asterisk (*) right way. This could be a light green arrow pointing towards the left, etc.		Yes	0	0	0	0	0	0	0	0						
1	3	2	1	5	Closer linking between the question and the extra data would help, because this would prevent the user from having to toggle back and forth b/w the right and left hand columns with every question. Every question requires not only perhaps reading of extra information, but finding out if the extra info is even there. If anything, any question with added info should have a asterisk to let the user know that she SHOULD be looking for more to read. Even better, if the added info was right above or below instead of a separate column.		Yes	0	0	0	0	0	0	0	0						
1	5	3	No	3	perhaps a historical account of any similar endeavors that have succeeded or failed.			0	0	0	1	0	0	0	0						
5	6	5	1	5	This is an generic comprehensive draft. Meaning that much of these questions could be blown out into matrices of there own. So my only recommendation is that more up-front research be provided for more specific topics. In other words break this into at least 4 different matrices. I am sure your intent was an over all feeling of the applicable usability of this document. In that sense I think this is an extremely useful tool. The written feed back from researchers and designers will eliminate language barriers and allow for out side help to make a difference on a very real level. As well as serving as research document to aid in finding funding and communication your over all need.			Na	0	0	1	1	0	0	0	0						
4	5	3	1	3			Yes	0	0	1	1	0	0	0	0						
5	6	3	No	4	More visuals regarding complex wording that the developer may not be familiar with. Further information on the country and people as a whole in the country. Get further information on the range of expenses that are "reasonable" for the project			0	1	0	0	1	0	0	0						
4	5	4	No					1	0	1	0	1	0	0	0						
5	4	4	1	4	More introductory information			1	0	1	0	1	0	0	0						
5	6	4	1	4			Yes	1	0	0	0	1	0	0	0						
3	3	1	No	NA				1	1	0	0	0	0	0	0						The areas I had concerns or questions about regarded the electronic devices and manufacturing. I did not feel my comments would have been helpful.
5	4	3	1	NA				1	1	1	1	0	0	0	0						
4	4	4	1	5				0	0	1	0	1	0	0	0						I feel as if I need more intimate knowledge of the situation in order to make a good choice.

Questionnaire Data (page 3 of 3)

					Space for commentary about reason for selection under each line.											
3	5	3	1	4		1	1	1	0	0	0	0	0			
					Yes											
6	5	5	No	NA		1	0	0	0	0	0	0	0			
5	5	4	1	4		1	0	0	0	0	0	0	0			
					(Don't have any suggestions)											
6	6	3	1	4		0	1	0	1	0	0	0	0			
					More background on the Rwanda Coffee Farmers. Are they Artistic People with a strong sense of culture? Are they illiterate? What is their education status? Are they competitive with one another?									more background info		
6	4	3	1	2		1	0	0	0	0	1	0	0			
4	4	3	1	4		0	0	0	0	1	0	0	0			
														I mostly wanted more research		
					Yes											
5	3	5	1	4		1	1	1	0	0	0	0	0			
					Yes											
4	5	4	1	4		0	0	0	0	0	0	0	0			
0	0	0	0	0	N.1	20	12	18	8	9	2	0	0			
3	7	0	0	1	N.0	15	23	17	27	26	33	35	35			
9	16	5	0	8		35	35	35	35	35	35	35	35			
4	5	6	0	9		57%	34%	51%	23%	26%	6%	0	0			
2	5	11	0	5		More detailed description	Comments on selection	More research	Questioning of data	Detailed images	Other					
9	1	6	0	2												
5	0	2	27	1												

APPENDIX B:

RAWANDA PAPER: BY MIKE SUN

Connecting the Rwandan Coffee Cooperatives: Economic Analysis of Network Deployments for Rural Rwanda

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Abstract

Under the USAID lead PEARL project, a number of Rwandan coffee cooperatives now sell high profit, specialty coffee to the international market. Essential to the project's success has been the "richness" in relationships developed between cooperatives and international buyers. As the project nears completion, management and operation responsibilities will be transferred from USAID directly to the local cooperatives. It is critical for the cooperatives to maintain and cultivate these vital business relationships. Currently however, none of the cooperatives have Internet connectivity and few have phone service. USAID wishes to deploy a low-cost, economically sustainable network to the cooperatives that will provide at minimum, e-mail capabilities.

Ten cooperatives are to be connected with varying levels of Internet service. Some cooperatives seek high bandwidth solutions that will support cooperative-run cyber-cafés, bandwidth re-

selling, and voice-over-IP, while others desire only connectivity adequate for e-mail. This work proposes several wireless network technologies and topologies capable of connecting the cooperatives. Economic models for WiFi (802.11), pre-WiMAX (proprietary OFDM), VSAT, GSM/GPRS, CDMA2000 1x, and CDMA2000 EVDO based deployments utilizing point-to-point, point-to-multipoint, and cellular-based topologies are constructed and analyzed. Resulting from the analysis are insights on proper technology choices—fixed-link versus cellular-based wireless deployments—key cost factors, and the impacts that NGOs and other external funding agencies have on local telecom tariffs.

1. Introduction

Devastated by the genocide of 1994 and by a collapse of international coffee prices throughout the 1990s, the Rwandan coffee industry partnered with the United States Agency for International Development (USAID) to foster the production and sale of high end, specialty coffee, capable of commanding high prices. Through managerial and technical support, the USAID Partnership for Enhancing Agriculture in Rwanda through Linkages (PEARL) project has successfully helped local coffee cooperatives grow, process, and distribute their high quality coffee beans to buyers worldwide. As a result, cooperatives under the program have seen their revenues quadruple and exports increase tenfold.

The high end, specialty coffee industry brands itself as "relationship" coffee. Purveyors of such coffee seek its uniqueness both in taste and in its origins. Marketed as more than just coffee, consumers are attracted by its regional uniqueness and its positive economic impacts on the lives of its growers. USAID/PEARL has done an extraordinary job in developing and nurturing these "rich" relationships cooperatives and international buyers from communicating logistical information such as production figures and quality ratings to providing valuable "soft" resources such as the personal stories of coffee farmers that had been afflicted by the genocide.

As the USAID/PEARL project comes to a close however, all managerial and business operations must be taken over by the cooperatives. Currently, none of the cooperatives have Internet access, and telephone service is sparse. The USAID Last-Mile Initiative (LMI) aims to provide at minimum, e-mail capabilities to the cooperatives. Higher bandwidth solutions will enable voice-over-IP (VoIP), rich web content, and higher fidelity media such as streaming video.

Survey work by Caine and Hargrove (2006) have revealed the strong desire of cooperatives for high bandwidth Internet services such as the World Wide Web and voice-over-IP (Caine and Hargrove 2006). Likewise, international buyers have indicated their interest in live video streams from coffee farms as a means of enhancing the "relational" experience in their coffee shops.

Even with the support of USAID/LMI, connecting all of the cooperatives and providing high bandwidth remains an economically challenging endeavor. This work aims to study in detail a range of potential wireless network solutions incorporating WiFi (802.11), pre-WiMAX (proprietary OFDM), VSAT, GSM/GPRS, CDMA2000 1x, and CDMA2000 EVDO technologies in various point-to-point, point-to-multipoint, and cellular-based arrangements. Economic models incorporating deployment costs and estimated revenue streams are then constructed for the proposed network solutions. Analysis of the resulting models reveals two major insights:

1. Cellular-based Wireless Wide-area network (WWAN) deployments such as GPRS, CDMA2000 1x, and CDMA2000 EVDO are the preferred solutions if enough aggregate demand exists within the coverage area; otherwise fixed-link WWAN deployments utilizing WiFi and WiMAX are more viable when specific locales must be reached and regional demand is uncertain.
2. Operating expenses such as human resources and bandwidth dominate the overall costs of these networks. Bandwidth tariffs generally rise exponentially as bandwidth requirements are increased, but can display great variability across technologies. This is

a result of the complex set of revenue and external funding streams telecoms receive that subsidize certain technologies deployments in differing ways.

2. Related Work

The corpus of work relating to network deployment for rural regions generally falls into three categories: high-level qualitative commentaries on factors critical to sustainable Internet access; case study reports on real-world deployment experiences; and economic analyses of deployment strategies and technologies.

Best and Maclay (Best and Maclay 2002) argue that disinterest of businesses and political entities in undertaking the provisioning of Internet access in rural is chiefly due to the misconception that markets do not exist for such endeavors, requiring economic subsidy and financial loss. They believe Internet access is sustainable given low capital and recurrent costs, diverse fees and services, proper use of network effects, appropriate policy, and sufficient local capacity. Several other works support the claims of Best and Maclay. Hudson cites the explosive growth of mobile phone services in rural areas and argues that demand does exist for Internet access (Hudson). Galperin (Galperin 2005) highlights the potential benefits of using WLAN technologies by theorizing about the potential low cost deployments involving WiMAX, and cites examples of successful WiFi deployments in Peru.

In contrast to high-level analyses, a number of projects have deployed experimental wireless networks in rural areas around the globe. The N-Logue project employed a Wireless Local Loop (WLL) network technology developed by the Indian Institute of Technology-Madras called

CorDECT, in providing low cost Internet access to rural regions in India (Narayanan, Jain et al. 2005). The Digital Gangetic Plains project developed and deployed a mesh network in the rural plains of India utilizing low cost WiFi links and equipment (Bhagwat, Sanghi et al. 2004). Improvements to the 802.11 protocol for long-distance use were made as a result of the project.

Most similar to our work is the economic analysis performed by Mishra, Hwang et al. (Mishra, Hwang et al. 2005) on the sustainability of various WLAN and WWAN technologies. Their model examines a deployment in Akshaya, India, and concludes that a network utilizing WiFi for the back-haul links and CDMA450 for the access network provides the lowest cost solution.

3. Project Setting

Rwanda is a small, landlocked country in East Central Africa comprised mostly of grassy uplands and hills with a total land area of roughly 26,000 square kilometers. With a population of over eight million inhabitants, it is the most densely populated country in Africa averaging 230 people per square kilometer ("ECA's Rwanda-Background", n.d.). Despite the high population density, the level of urbanization remains low at 6.4%. The majority of the population engaged in subsistence agriculture. As a result, Rwanda remains an extremely poor country with a GDP per capita of US$210 (Nsengiyumva and Stork 2005).

Three telecoms/ISPs currently operate in Rwanda. MTN-Rwandacell is the dominant mobile telecommunications operator with a GSM/GPRS network covering an estimated 70% of Rwanda. Artel has been addressing rural telephony through their satellite-based VSAT deployments, but performance and penetration remain low. Terracom, a new telecom and ISP is

aggressively implementing a fiber-backed network and deploying CDMA2000 coverage. Their acquisition of the incumbent government telecommunications provider, Rwandatel, means they operate much of the existing wired telecommunications infrastructure (Nsengiyumva and Stork 2005). Major urban areas such as Kigali are connected through leased lines, frame relay, ISDN, with newer technologies such as fiber and CDMA2000 EVDO now entering the market. The rural areas however still lag far behind in connectivity. Overall, Internet penetration remains extremely low at 0.3% (Stats).

Deploying networks to the cooperatives in rural Rwanda presents unique challenges and constraints. Such rural areas are characterized by low disposable income, high cost per line, weak economies of density, and poor infrastructure to support the operation and maintenance of networks (Gasmi and Virto 2005). These areas are coverage-limited, where demand is elastic relative to geographic area covered, and not capacity. The power infrastructure in the rural areas of the cooperatives remains primitive with many areas without access to any power. Transportation around many cooperative sites is limited, with access restricted by hilly terrain and poor roads.

Figure 5 - Coffee cooperatives and cell base stations

Figure 5 shows the geographic distribution of the cooperatives and existing cellular base stations around the country. Many cooperatives are within reach of existing base stations[1]. The liberal regulatory environment of Rwanda also allows several technologies to be used for connecting the cooperatives—voice-over-IP (VoIP) is permitted and the 2.4 GHz frequency spectrum is unlicensed. These factors bring optimism that innovative, cost-effective solutions can be found to network the cooperatives.

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[1] Cellular base stations have a coverage radius of roughly 30 km. Obstacles such as hills, dense vegetation, and other factors can greatly affect actual ranges.

4. Technologies

In the rural areas of the cooperatives, low population densities and high costs of building wired infrastructure necessitate the need for wireless network technologies. Wireless technologies ar used for both wide area networks (WANs) and local area networks (LANs).

4.1. Network Topology

Wireless WANs (WWANs) are generally constructed in two tiers: a backbone network comprised of Points of Presence (POPs) interconnected by backhaul links and access networks that connect POPs to endpoints such as telecenters or cybercafés. WWAN access networks can be implemented with a range of topologies, generally falling under two categories. Fixed-link networks provide point-to-point, point-to-multipoint, or multipoint-to-multipoint (mesh) connectivity between stationary endpoints. Cellular networks provide access for entire coverage areas to both stationary and mobile clients. Ranges for both fixed-link and cellular-based networks can reach 30 km. Sites with access to the WWAN access network can further share their network connectivity with local entities through the use of a wireless LAN (WLAN). Figure 6 illustrates WWAN and WLAN network topologies.

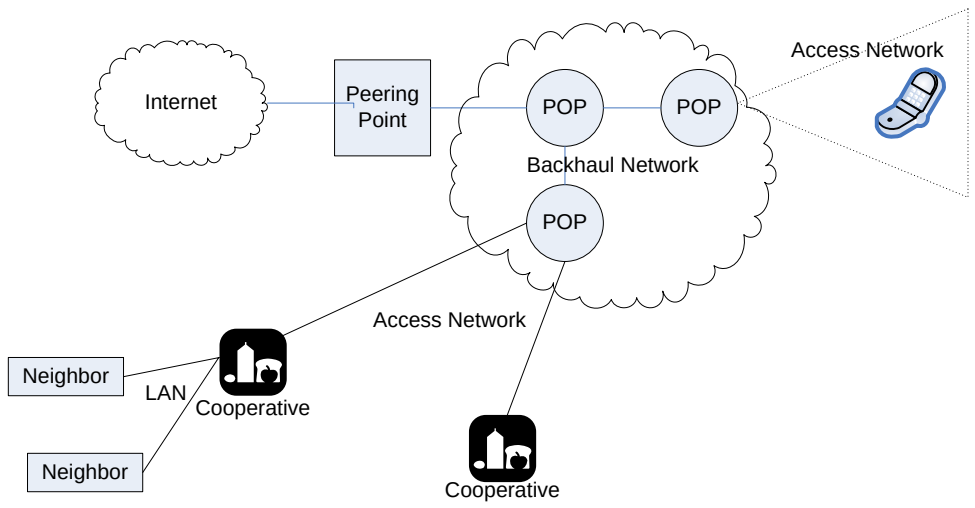

Figure 6 - WWAN and WLAN topologies

4.2. Network Technologies

Since a backhaul network exists in most parts of the country, we focus our attention on access networks.

WiFi (802.11g): Originally designed for short-range LAN use, the use of higher power transmitters and high-gain direction antennas enables long range point-to-point links of up to 30 km to be achieved. 802.11g operates in the unlicensed 2.4 GHz frequency spectrum, providing both high capacity and long range. The standard's immense popularity has allowed significant commoditization of equipment resulting in very low costs. For our work, we have chosen the Cisco 1300 series of 802.11g access points and bridges.

Pre-WiMAX OFDM: WiMAX technology promises much greater capacity and range than WiFi through the use of a technique called orthogonal frequency-division multiplexing (OFDM). WiMAX has only recently been ratified, and equipment has yet to appear in marketplace. We have chosen to evaluate other OFDM-based technologies, so called pre-WiMAX equipment, as

representative of WiMAX's capabilities and costs. Motorola's line of Canopy solutions provides OFDM equipment capable of operating in the 2.4 GHz (unlicensed) frequency spectrum. Specifically, we evaluate the Motorola Canopy 2.4 GHz, 10 Mbps line of backhaul equipment[2]. This equipment provides point-to-point links reaching up to 30 km.

VSAT: VSAT satellite technology provides network connectivity to sites without the need for a backhaul network. Artel is the primary operator of VSAT services in Rwanda, and we have performed our evaluation based on the performance and costs figures they offer.

GSM/GPRS: A second generation (2G) cellular technology, GSM is the voice communication component, while GPRS provides data services of up to 48 Kbps. Depending on how GSM/GPRS base stations are configured, coverage can extend up to 30 km. Modeling their costs and revenues can be extremely difficult however; such information is often kept under wraps by telecoms and equipment vendors. For that reason, when modeling the GSM/GPRS, we rely on the pricing of services offered by MTN-Rwandacell.

CDMA2000 1x/EVDO: A third generation (3G) cellular technology, CDMA2000 provides both voice and high bandwidth data services. CDMA2000 1x allows up to 144 Kbps of data bandwidth while the newer revision, CDMA2000 EVDO, can deliver up to 3.1 Mbps on the downlink and 1.8 Mbps on the uplink. Both technologies share similar ranges of up to 30 km.

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[2] Though it is marketed for use in a backhaul network, we are evaluating its use for a long-range point-to-point access network.

Similar to GSM/GPRS, data equipment costs and revenue are difficult to obtain; we therefore base our models on subscription prices offered by Terracom.

5. Methodology

Our analytical approach evaluates the costs and potential revenues associated with deployments at various cooperatives for each technology, utilizing the net present value instrument to determine economic viability over a ten year period. Our approach:

1. Models the costs of various fixed-link WWAN access technologies.
2. Models the costs associated with various WLAN technologies.
3. Determines the network needs and estimates potential revenue streams for the various types of cooperatives.
4. Determines the net present values (NPVs) of deployments for four types of cooperatives utilizing various WWAN and WLAN technologies.

5.1. Cost Modeling Fixed-Link WWAN Access Technologies

We model the capital expenditure (CAPEX) and operating expenditure (OPEX) costs associated with WiFi and Motorola Canopy 2.4 GHz for a point-to-point WWAN access network over a ten year period. CAPEX items include base station equipment and customer premises equipment as well as installation charges. OPEX items include maintenance and power costs. The technology with the lowest aggregate cost is chosen as the most viable fixed-link WWAN technology.

5.2. Cost Modeling WLAN Technologies

The costs associated with WLANs based on WiFi, Motorola Canopy 2.4 GHz, and Motorola Canopy 900 MHz technologies are modeled. Aggregate costs over a ten year period for the various WLANs are calculated. The lowest cost technology is then chosen to be the baseline WLAN technology choice for the remainder of the analysis.

5.3. Determining the Needs and Capabilities of the Cooperatives

There are ten cooperatives requiring varying forms of Internet connectivity. We have categorized them into four types according to their needs and characteristics.

- The *Sub-POP cooperative type* resides in a locale with a substantial business district. There is enough demand to support a cooperative-owned cybercafé and the reselling of capacity to local schools, health centers, and government offices. They require fairly high bandwidth (at least 384 Kbps) and a WLAN network to share Internet connectivity with neighboring entities.
- The *Telecenter cooperative type* operates a cybercafé, but does not resell bandwidth to local entities. 256 Kbps of bandwidth through the WWAN is sufficient.
- The *Rich cooperative type* desires high quality connectivity (at least 128 Kbps), but does not run a cybercafé or resell to local entities.
- The *Minimalist cooperative type* resides in an isolated locale and requires minimal connectivity for e-mail use (48 Kbps).

5.4. Assessing the Overall Economic Viability of Deployments

Using a discount rate of 15% over a ten year period, we model the NPVs of deployments utilizing the most lowest cost fixed-link WWAN technology (determined in Section 5.1), VSAT,

GSM/GPRS, CDMA2000 1x, and CDMA2000 EVDO for all four cooperative types. When a WLAN is needed to resell capacity to local entities, the lowest cost WLAN determined in Section 5.2 is used.

CAPEX items:

- Base station equipment (access points, antennas, routers, power supplies, wiring)
- Customer premises equipment (computers/laptops, network cards, routers, wiring, power supplies)
- Mounting equipment and installation costs

OPEX items:

- Maintenance and power costs
- Personnel expenses (cybercafé manager)
- Bandwidth/Internet subscriptions

Each cooperative is assumed to be capable of affording US$220 annually for Internet access by itself. A cybercafé run by the cooperative is estimated to earn US$3198 annually. For *Sub-POP type cooperatives*, it is assumed that bandwidth is resold to three neighboring entities, generating combined revenues of $US660 annually.

6. Economic Analysis

We report in this section the results of our economic models, highlighting key cost factors and preferable technology choices.

6.1. Costs of WLANs

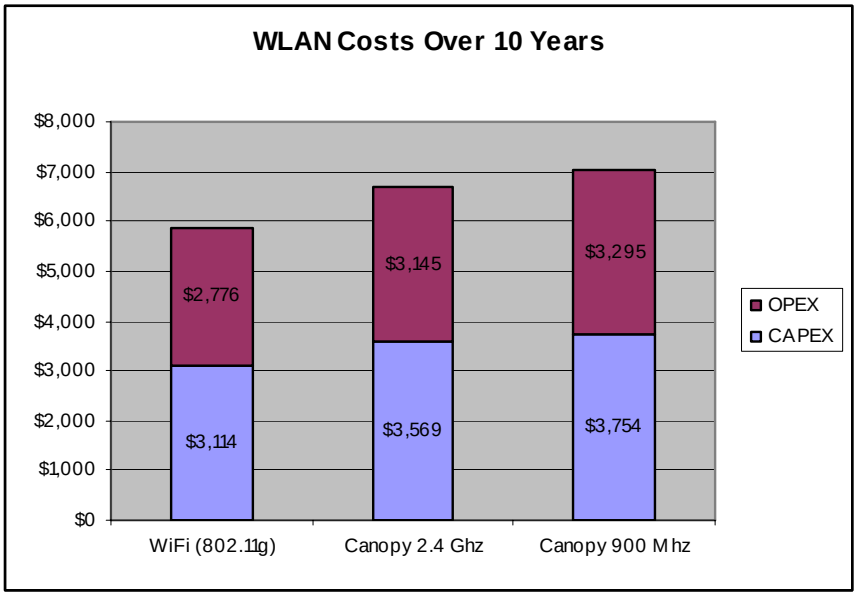

Figure 7 - Aggregate costs of various WLAN technologies over a 10 year period

Figure 7 illustrates the costs associated with deploying a WLAN at a cooperative site, allowing three other local entities can share network connectivity. For all three technologies, the ratio of CAPEX to OPEX costs is nearly the same, roughly 1.1. Though all are relatively comparable in cost, a WLAN based on WiFi provides the lowest aggregate cost. A WiFi WLAN is used as the baseline for our other models.

6.2. Costs of Point-to-Point WWAN Access Technologies

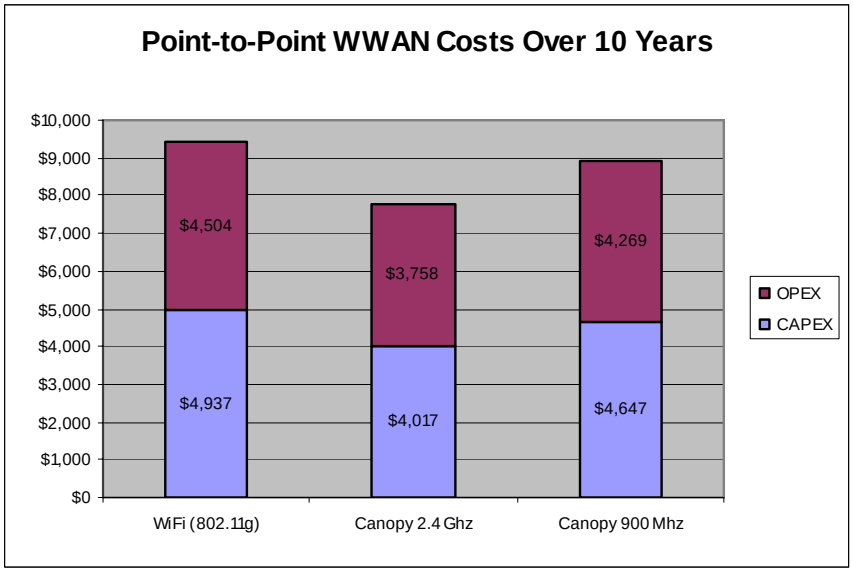

Figure 8 - Aggregate costs of various WWAN access technologies over a 10 year period

We see in Figure 8 that CAPEX and OPEX for point-to-point WWANs have roughly the same ratio as in the WLAN case. However, the Canopy 2.4 GHz solution becomes the lowest cost solution when long range is required.

In examining the CAPEX structure for the three technologies, we see that equipment costs are distributed differently. Figure 9 illustrates that for WiFi, the costs are fairly evenly distributed between the POP and the cooperative site. In the case of Canopy 2.4 GHz, a significantly larger proportion of the cost is borne at the cooperative site. For Canopy 900 MHz, the situation reverses as the majority of cost is located at the POP.

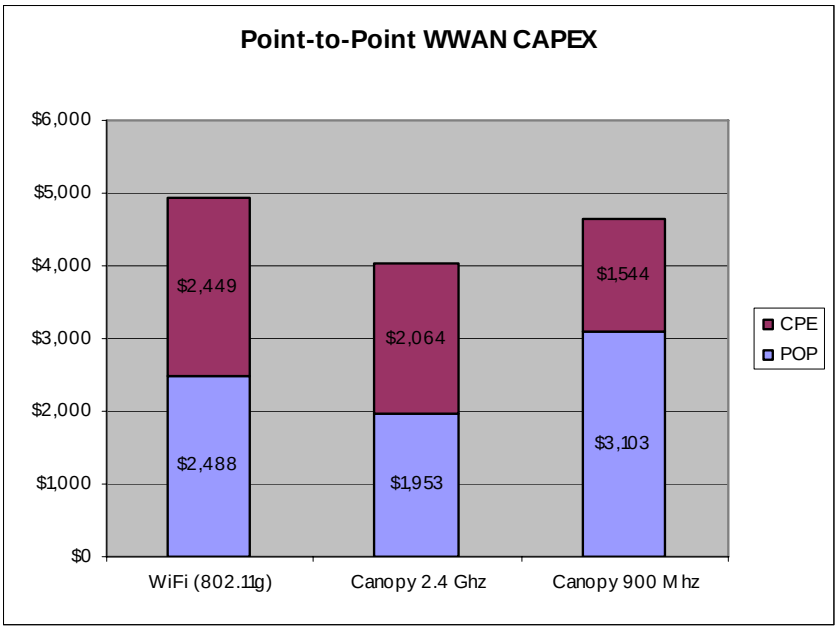

Figure 9 - Point-to-point WWAN CAPEX

6.3. Overall Viability of Technology Deployments

After determining that WiFi is the lowest cost solution for WLANs and Canopy 2.4 GHz for fixed-link WWAN access networks, we proceed to determine the overall economic sustainability of deployments utilizing these technologies in addition to VSAT, GSM/GPRS, CDMA2000 1x, and CDMA2000 EVDO. We derive NPVs over a 10 year period for each technology solution and cooperative type in Table 3.

Table 3- NPVs of various technology solutions

Technology	Net Present Value			
	Minimal Coop	Rich Coop	Telecenter Coop	Sub-POP Coop
Canopy 2.4 GHz	-$8,072	-$12,105	-$15,814	-$39,377
VSAT	-	-$29,400	-	-
GSM/GPRS	-$2,352		-	-
CDMA2000 EVDO	-$8,309	-$10,999	-$16,729	-$30,024
CDMA2000 1x	-$4,814	-$8,847	-$17,804	-$28,952

None of the proposed solutions produce a positive NPV for any cooperative. For the *Minimal cooperative type*, existing GSM/GPRS from MTN-Rwandatel is the most cost effective. For a *Rich cooperative type*, the existing CDMA2000 1x service provided by Terracom proves most cost effective. As bandwidth requirements increase, the Canopy 2.4 GHz fixed-link solution becomes the most viable solution. Surprisingly however, as bandwidth requirements increase to 384 Kbps for the *Sub-POP cooperative type*, the cellular-based CDMA2000 EVDO technology becomes the most cost effective solution.

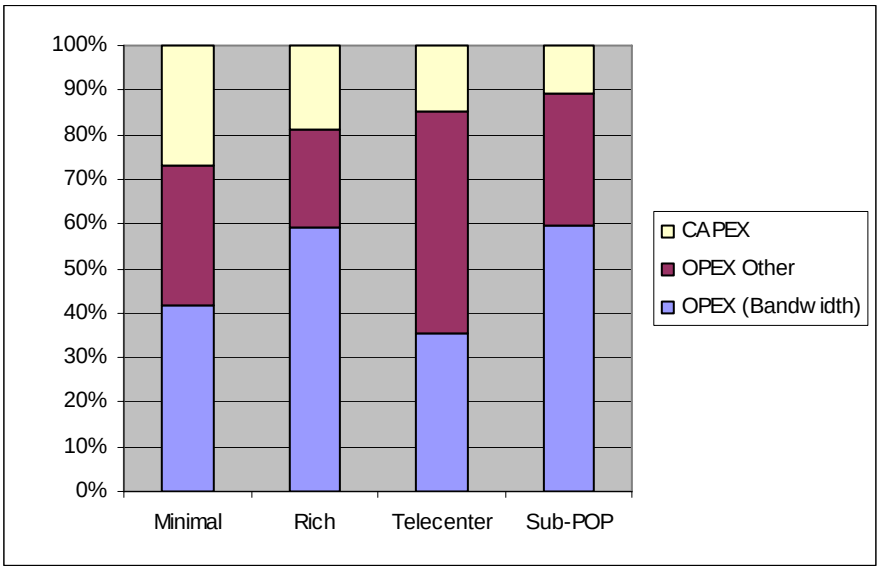

Figure 10 - Bandwidth as a fraction of costs for Canopy 2.4 GHz

We investigate further how varying bandwidth requirements affect technology choices. In Figure 10, we see that bandwidth costs make a significant portion of the total cost of a 2.4 GHz solution, at least 35% for any given cooperative type. Figure 11 illustrates that at lower bandwidths (64 Kbps, 128 Kbps), CDMA2000 1x has the lowest cost of bandwidth. When 256 Kbps of bandwidth is needed, the cost of bandwidth rapidly increases for CDMA2000 1x, while the cost of bandwidth for a Canopy 2.4 GHz deployment grows at a much lower rate. But when

384 Kbps of bandwidth is needed, the cost of bandwidth skyrockets for the Canopy 2.4 GHz deployment, resulting in the CDMA2000 1x deployment having the lowest bandwidth costs. This leads to the conclusion that the price of bandwidth for each technology deployment is the dominant factor in determining overall viability, and not equipment costs.

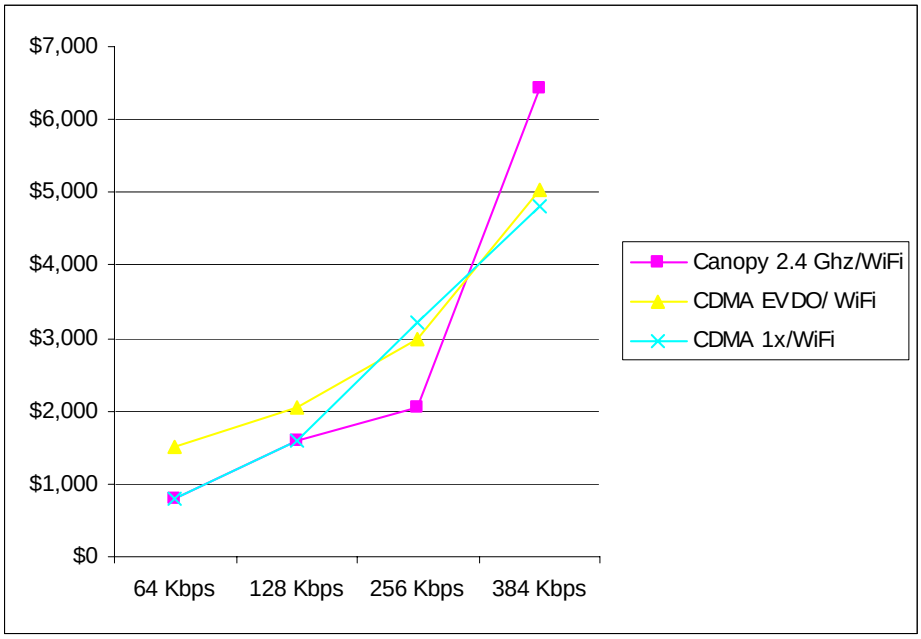

Figure 11 - Internet bandwidth/subscription costs

7. Discussion

Bandwidth as the Key Cost Factor

The analysis has shown the sensitivity of cost effective deployments to bandwidth prices. More important than equipment costs and the transport capabilities of access technologies is the technology's ability to determine the price at which it can obtain bandwidth. As was seen, the pricing for bandwidth can vary greatly across technologies and capacity. Such disparate and non-linear pricing of bandwidth may be surprising since all technologies solutions eventually

utilize the same backhaul network. One reason is that fixed-link solutions do not allow much overbooking of leased bandwidth, while cellular-based technologies can take significant advantage of such a scheme. But more significant reason is due to the complex pricing structures developed by the bandwidth providers. Raw backhaul bandwidth costs—the actual costs to the backhaul providers—grows exponentially as bandwidth capacity is increased. It is often the case however, that funding from various donor organizations and government entities will be earmarked for particular technologies or deployments. For example, CDMA2000 deployments may have a large portion of their costs subsidized and this subsidy is then reflected in the reduced tariffs for CDMA200 bandwidth. As a result, what determines cost-effectiveness for network deployments in Rwanda is not necessarily the lowest cost technology solution, but the technology solution that has received greatest subsidy or support within a telecom.

Fixed-link versus Cellular Deployments

The analysis has shown that both fixed-link and cellular-based deployments can provide the most economically viable solution depending on bandwidth needs. All of these models have so far assumed that cooperatives are within range of an existing cellular tower. For point-to-point WWAN technologies, this means that costs for a POP include only the WWAN equipment, and not the expense of physical tower construction. Cellular solutions such as GSM/GPRS and CDMA2000 1x/EVDO were modeled under the assumption that such services were already available or would be made available to the cooperatives at the current market prices offered by the telecoms. A corollary to this assumption is that existing cellular deployments often have enough aggregate demand in their coverage areas. If a cooperative is not within range of an existing tower however, the costs and viability of cellular deployments changes dramatically.

For cellular operators, the rough cost of deploying a new base station (tower and equipment) exceeds US$100K. In order for the operator to offer their advertised subscription prices, enough latent demand would have to exist in that locale to offset the large capital cost. These rural regions are marked by uncertainty of demand and provisioning of new base stations can be a risky endeavor.

When specific sites in areas in which cellular towers do not already exist must be connected, it is a less risky proposition to deploy fixed-link access networks. Even with the cost of new towers factored in, the total CAPEX of such deployments remains below US$40K—well below the cost of new cellular base stations.

8. Conclusion

We have evaluated the costs for several technology deployments capable of connecting the ten coffee cooperatives around rural Rwanda. Depending on the needs of individual cooperatives, various technologies offer the lowest cost solution. These choices are dictated less by actual technical capabilities and costs, but rather by bandwidth tariff structures offered by backhaul providers. When a cooperative is not within range of an existing base station tower and latent demand in the area is uncertain, fixed-link WWAN technologies offer the most cost effective, risk averse solution.

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APPENDIX C:

RWANDA PAPER: BY KELLY CAINE AND WALTER HARGROVE

Information and Communication needs of Rwandan Coffee

Stakeholders

Kelly E. Caine, Walter E. Hargrove & Michael W. Sun

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Abstract

Rwanda is one of the poorest countries in Africa. Even with few natural resources, no ocean ports, and serious social issues, Rwanda has the potential to flourish economically. High end Arabica coffee beans, which command a high price on the international market, are grown with great success in Rwanda. Our research examined the current communication network in the Rwandan coffee agribusiness and evaluated the system with an eye toward improvement. We also examined the potential user's familiarity with communication devices. Some of the key findings show that both high frequency domestic communication and high cost international contact could benefit from the application of ICT's (Information and Communication Technologies). In addition, despite having little experience using most ICT's, Rwandan farmers are eager to integrate ICT's into their everyday agricultural practices. In addition to the contribution of the research findings, a new method of displaying interaction networks is presented.

Information and Communication needs of Rwandan Coffee Stakeholders

Despite the promise of economic development through information and communications technology (ICT) most ICT projects in developing countries fail (Heeks, 2002). The failure of ICT projects in developing countries can be attributed to Design-Reality gaps which are the mismatches between Information System designs and local user realities (Heeks, 2002). For these gaps to be filled the information and communication needs and expectations of the users of ICT's need to be identified and incorporated into the design of a system before the implementation phase. The appropriate time to identify these needs is while a project is still in the planning phases. In addition to design reality gaps, the intensity of the information needs of each user may vary thus varying the type of ICT required to meet those needs (Donner, 2004).

One ICT for development project that is still in the planning phase is a program aimed at improving the communication capabilities among a group of coffee industry stakeholders in Rwanda. Over the past few years, USAID has been actively involved in providing management and technical support to coffee co-operatives in the Rwandan coffee sector. This support has allowed a trend toward developing the relationships which facilitate the sales of specialty coffee which brings much higher prices than traditional coffee. These higher coffee prices mean more profits for coffee cooperatives and farmers which may lead to increased economic development in rural areas of Rwanda. However, for the success to continue, the coffee cooperatives and farmers must begin to manage their business relationships on their own. A critical part of managing these business relationships includes communicating between customers and suppliers who are mostly European or American. These European and American customers often initially travel to meet the suppliers face to face. However, once the relationship is established, many buyers expect to be able to have instantaneous contact with the farms and co-ops via telephone

and through email. To remain competitive on the global coffee market, the cooperatives need to have access to such communications technologies. USAID through its Last Mile Initiative (LMI) hopes to encourage the implementation of these technologies in the co-operatives (LMI Proposal – Rwanda). However, for the project to be successful long term the design of the information and communication technologies must not fall prey to design-reality gaps. Before a technology is chosen and implemented in Rwanda the information and communication needs of the potential users of the system must be assessed.

Background on Harvesting and Coffee Processing

The quality of the coffee bean is greatly determined by more than the genetic properties of coffee beans. The environment, cultivation methods, and post harvest processing (i.e. storage, hulling, sorting, and roasting) have additional considerable effects on the quality of the coffee. The remaining information in the *Harvesting and Coffee Processing* and *Coffee Bean Quality Assessment* is drawn from Wintgens (2002) book *Coffee: Growing, Processing, Sustainable Production. A Guidebook for Growers, Processors, Traders, and Researchers.*

Both the robusta and arabica coffee bean's basic structure made up of an external skin called the exocarp which turns red or yellow when ripe, a mucilaginous flesh called the mesocarp or pulp and two grains or beans called endosperm. There are three ways to process the coffee bean; a dry-process (natural coffee) which dries the entire cherry (most often robusta) until the whole hull is removed mechanically, wet-processed (washed coffee, primarily arabica) which requires large amounts of water to remove the exocarp and part of the mesocarp, and semi-dry process (pulped natural) which blends steps of both dry and wet- processing. The type of processing used affects how harvesting must be done.

There are two common methods of manual harvesting: selective and stripping. Selective processing produces the highest quality bean and greatly affects the quality of the final product. However, selective harvesting requires a well trained labor force to select the ripe cherry from the immature cherry on the tree. In contrast to the selective method the stripping method harvests all of the cherries in one picking round which can lead to unripe cherries being processed. To provide the best quality coffee bean, when using wet-processing techniques, all of the cherries must be ripe because cherries at other maturation levels can jeopardize the flavor of the rest of the beans.

Rwandan coffee farmers typically use selective harvesting. When most of the cherries that have been picked are ripe, as often occurs using the selective method, then many steps in processing like sifting and flotation can be skipped. The next step, pulping, utilizes small horizontal drum pulpers to separate the pulp from the parchment, or outer layer of the coffee bean. After pulping, the two remaining layers, the mesocarp and coffee bean, are placed underwater for fermentation. The beans do not actually ferment, rather the remaining mucilage ferments allowing it to be more easily separated from the bean. Once fermentation is complete the labor and water intensive process of washing occurs. During washing a wooden paddle is used to move the coffee beans through the water causing the remaining mucilage to be dislodged from the beans.

Once the beans are cleaned the next step is the drying phase. The objective of drying the beans is to lower the moisture of the bean thus allowing them to be stored without risk to the coffee quality. In Rwanda, coffee beans are dried outdoors on large porous tables using sunlight as a drying agent. Using this sun drying process, the beans must be frequently revolved to maintain the appropriate temperature. Once dried the beans are weighed and then bagged into

sisal bags for storage or export. Proper storage can affect the quality of coffee and must be carefully executed. The green coffee is typically roasted in the port cities of the country of consumption.

Coffee Bean Quality Assessment

Even with recent improvements correct identification of physical defects in green coffee remains difficult. The quality of green coffee is the result of interactions between variables such as bean type, soil, climate, husbandry, latitude, altitude, luminosity, harvesting, processing, and storage. The flavor of the coffee is the most important factor in measuring the quality of the coffee bean. However, the overall bean flavor is highly susceptible to contamination by contact with spoiled beans that may occur between harvesting and storage. Rigorous methodical procedures in selecting and maintaining the ideal beans are the key to high quality coffee flavor. "Cupping" is the evaluation method used to objectively evaluate the coffee bean quality. Cupping often occurs twice in the coffee industry, once just after the coffee has been processed and then again at the destination port (usually in the United States or Europe). The Cupping scores are documented by both the sellers and buyers and then compared to determine final price per pound.

Determining Information Needs

Although there is information available about coffee production in general, there is very little information about the specific information and communication needs at each stage of the process. For an effective ICT solution to be developed to help Rwandan coffee farmers maintain contact with buyers from around the world, information about the needs of the stakeholders must be obtained. The purpose of this study was to perform an information needs assessment which would lay the foundation for the implementation of an ideal commutation structure for all

stakeholders. First, we mapped the pathways through which information is currently transferred among stakeholders. This information was critical to uncovering the communication pathways through which information currently flows and was also used to understand how information should ideally flow. Second we examined types of information that was needed by each stakeholder. This information served as a basis for recommendations about the best method for transferring that information and helped us distinguish between information which may be useful to all stakeholders and information which may only be useful to one stakeholder. Finally we explored the technology familiarity and preferences of the coffee farmers and co-op members who will be asked to use this technology.

Method

Participants

A total of 61 participants (25 women and 36 men) ranging in age from 18 to 60 participated in the focus group portion of the study. Of these participants 29 (14 women and 15 men) were also interviewed about their technology experience. In addition, of those participants who were interviewed about their technology experience, 14 (6 female, 8 male) were also interviewed about their technology preferences. All participants were either coffee farmers or coffee co-op members living and working in rural Rwanda. For the most part participants were educated and literate (see Table 1 and Figure 1).

Table 4. ***Overall Demographic and Educational Characteristics of Participants***

		Gender	
Variable		Male	Female
N		36	25
Age			
	Mean	38.28	31.44
	SE	2.07	2.1
Education			
	None	2.8%	4%
	Some	63.9%	32%
	High School	30.6%	64%

Missing	2.8%	0%

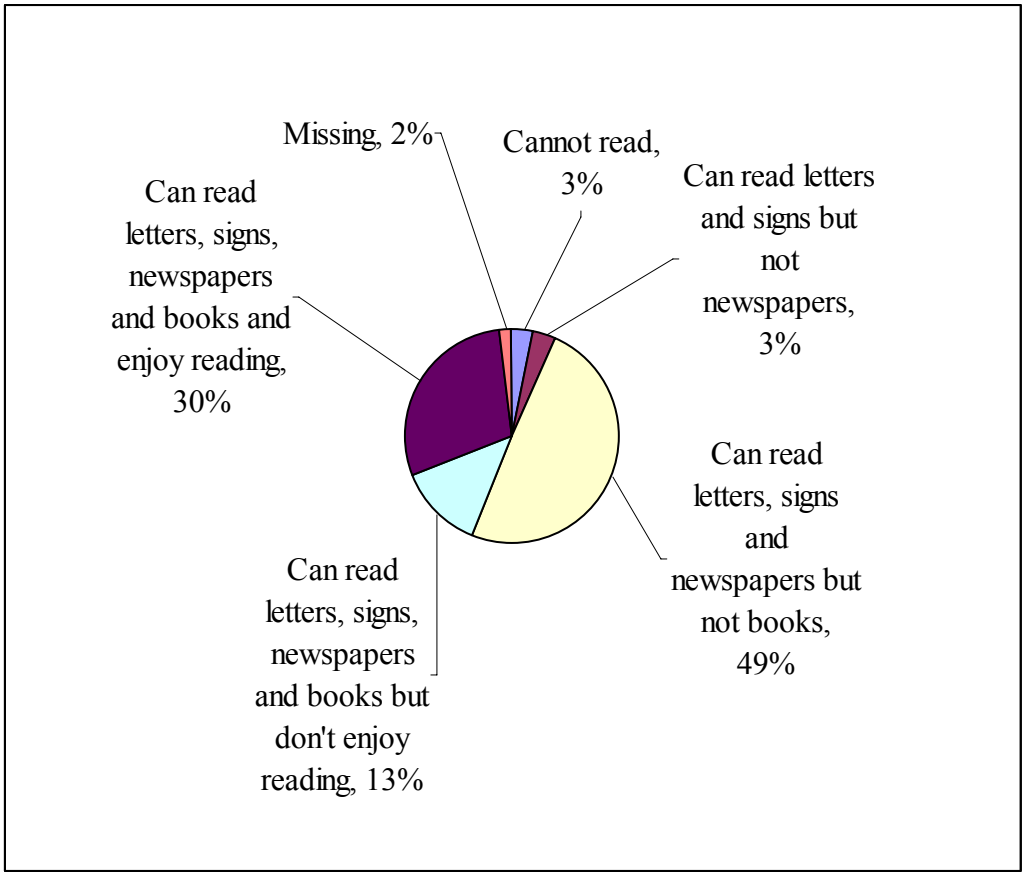

Figure 12. **Literacy of Participants**

Co-op's were selected on the criteria of being representative of all of the co-ops involved in the PEARL project. The selection of co-ops for this study was made by the head of the PEARL program on the basis of each co-op's geographical location, proximity to a population center and current technology situation (including power and telephone line availability). The co-ops that were selected were: Karaba, Mugombwa, Musasa, Maraba, Nyakizu and Rusenyi (see Figure 2) although no data were collected at Rusenyi due to a Gachacha hearing. Gachacha hearings are hearings where community members gather to decide the fate of neighbors who were involved in the 1994 genocide.

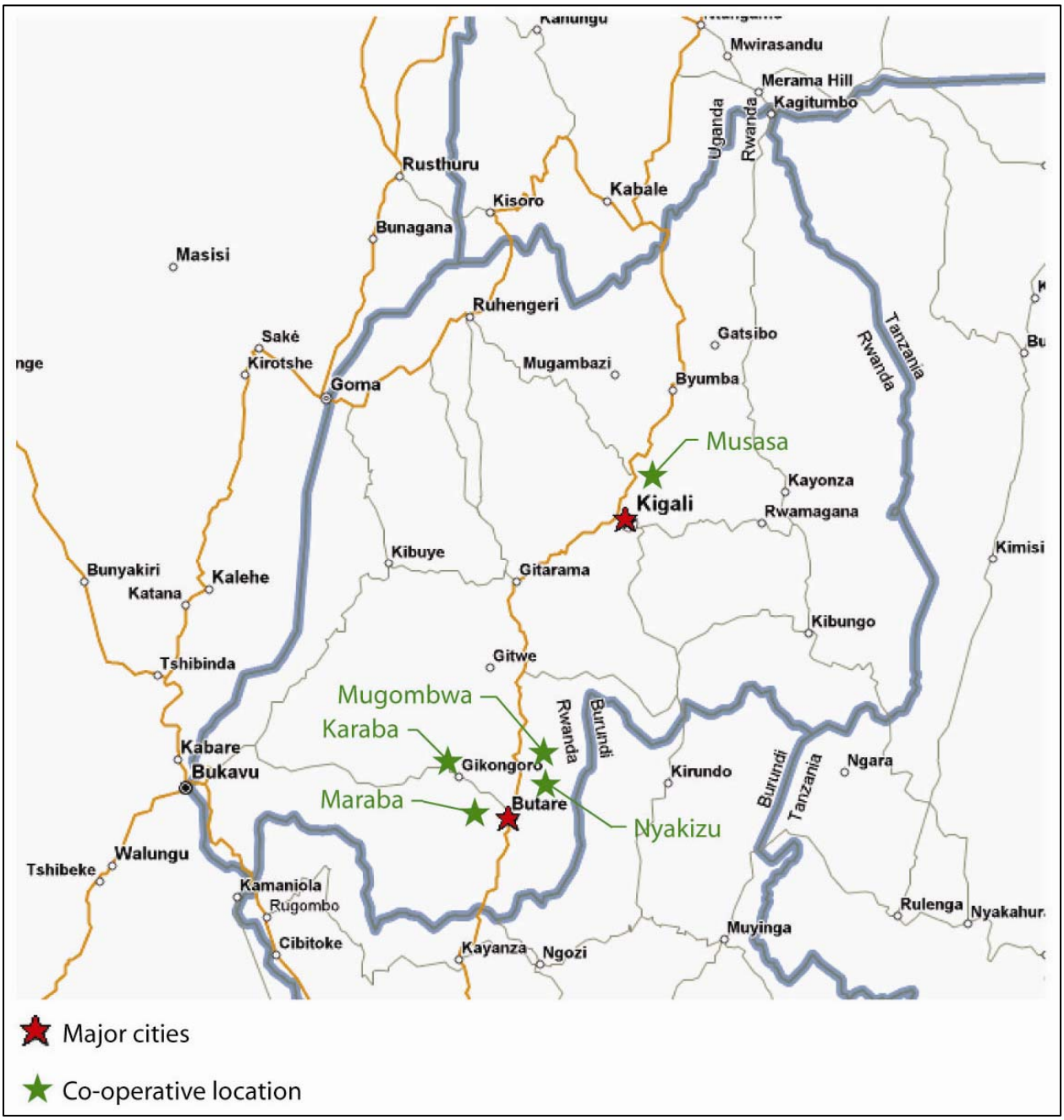

Figure 13. **Map of Coffee Co-ops**

Participants were recruited via word of mouth. Each co-op was contacted in advance by the PEARL communications officer and asked to invite interested members to participate. Although participants were not formally compensated for their time (and were told they would

not be ahead of time), members of the research team did distribute small gifts as tokens of appreciation.

Design and materials

Demographic information was obtained using a verbally administered questionnaire. A copy of this questionnaire is given in Appendix A. Current communication situation and ideal communication situation were assessed through the use of a focus group. The focus group methodology was chosen because it allows a large amount of data to be collected in a short period of time and because of the synergism that is common in focus groups. Specifically, we wanted each of the group members to be exposed to what other members were saying, hopefully triggering them to recall some communication experience or desire. The purpose of the "current communication" portion of the focus group was to identify who communicates with whom, how the communication takes place, and what the communication is about whereas the purpose of the "ideal communication" portion of the focus group was to identify who the co-op members would like to be able to communicate with and what information they would like to communicate. A copy of the focus group script is given in Appendix B.

Technology familiarity was assessed through individual interviews about the participant's technology experience. Cards illustrating common communication methods (both technological and non-technological) were used to cue participants to recall which type of communication technologies they may have had experience with in the past. The technology experience interview as well as examples of the cards used in this interview are given in Appendix C.

Technology preferences were obtained using a technology preferences interview. The same cards as used in the technology familiarity interview were used in the technology preferences interview. The technology preferences questionnaire is given in Appendix D.

All focus groups and interviews were translated into and administered in Kinyarwanda.

Procedure

The protocol for the focus group was similar but not identical at all co-ops. After giving informed consent, participants were seated in a large room or outdoor pavilion and read the introduction of the focus group script. At all but the Mugombwa co-op (which skipped this portion of the focus group due to time constraints), the groups were next asked about the current communication situation. Participants were encouraged to feed off each others answers and to come to a consensus about the types of communication used and what the communication was about before moving on to another communication type. After the group decided that they had exhausted the list of current communication methods the moderator moved on to the "ideal communication method" script (the Mugombwa co-op did do this portion of the focus group). Again participants were encouraged to come to a consensus about who they would like to communicate with and what they would like to communicate with them about. After the group decided they had exhausted the list of who they would like to communicate with the focus group portion of the study was complete.

Responses to the focus group session were recorded real-time by two of the research team members independently and later compared for consistency. Any comments recorded by one, but not both of the research team were dropped from analyses.

Immediately after the focus group portion of the study participants who were selected as representative of the group (in terms of age, gender and job (i.e. co-op president, member or farmer)) by a member of the PEARL staff, were asked if they would like to participate in the individual interview portion of the study. All participants who were asked if they would like to participate in this portion of the study did in fact participate. For the technology familiarity

section participants were given a set of cards (described in the materials section) and asked to select the communication methods they were familiar with. Participant's responses were recorded by a member of the research team.

To obtain technology preferences a sub-set of participants from 3 of the co-ops (Karaba, Mugombwa and Musasa) also completed the technology preferences interview. For this section participants were asked to rank the communication technologies in terms of which they would like to use, which they thought were most useful in the coffee business and which they thought were easiest to use. Participants ranked the technologies by placing the cards in order on a table or bench. A member of the research team recorded the order of the cards.

Results

Interaction networks were derived from the focus group data by laying out the communication stakeholders in an evenly spaced circular pattern. The current and desired interactions were plotted between the stakeholders. This graph provides a visual representation for analyzing the results. The interaction network charts demonstrates graphically how elements within the Rwandan coffee system relate. Both current Rwandan coffee interaction network (Figure 2) and the preferred enhancement of new Rwandan coffee interaction network (Figure 3)

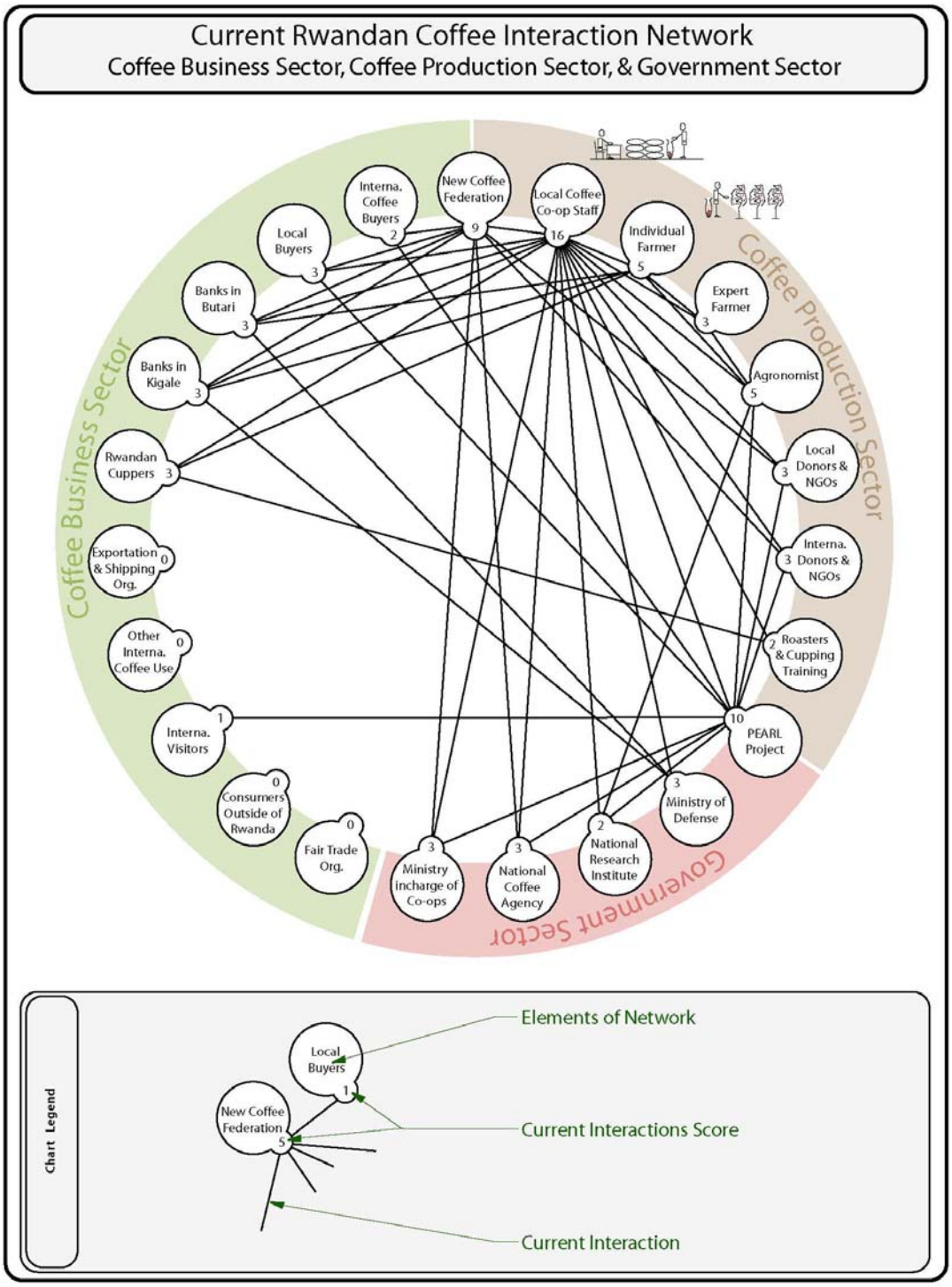

Figure 14 **Current Rwandan Coffee Interaction Network**

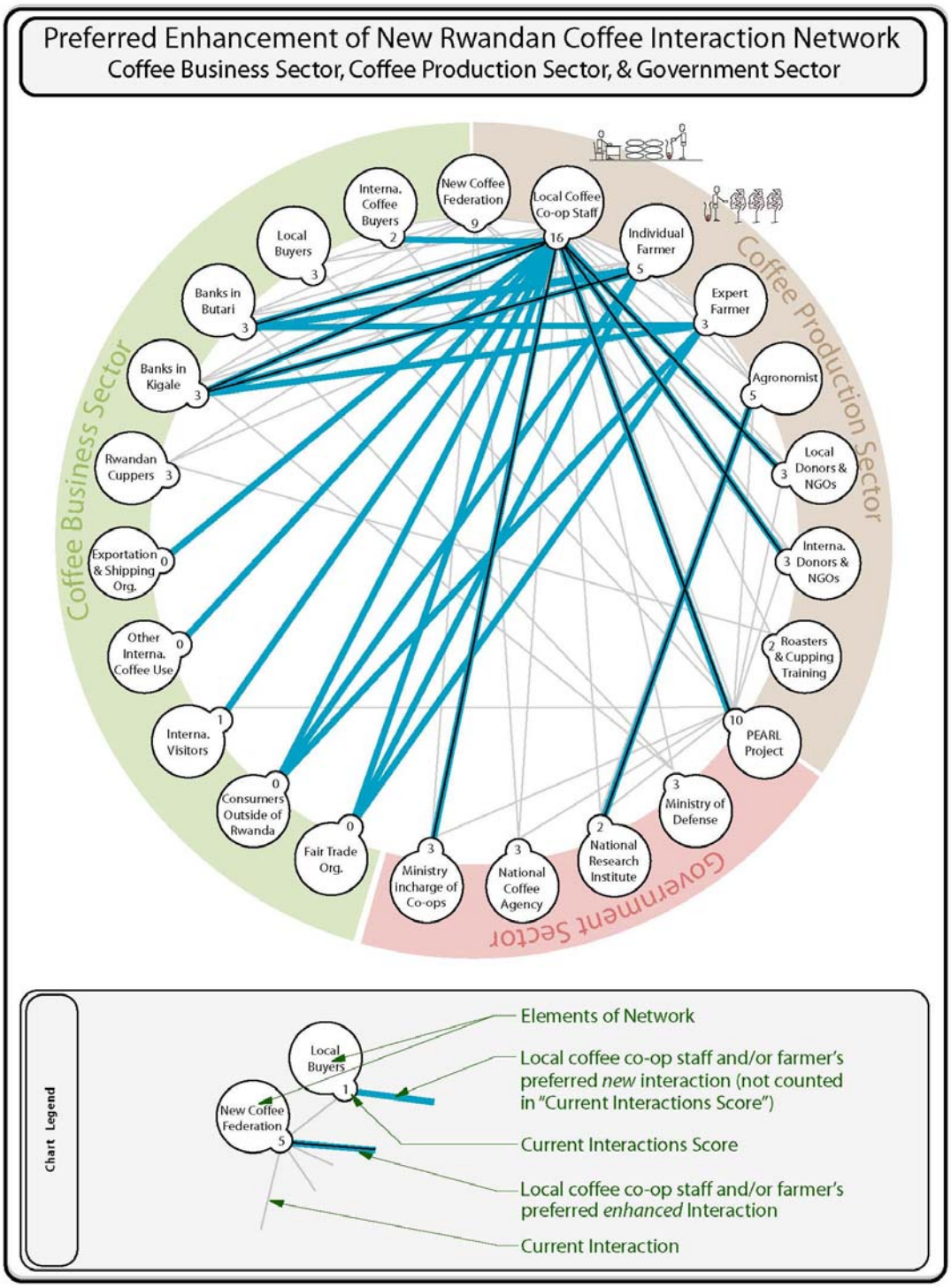

Figure 15. **Preferred Enhancement of Rwandan Coffee Network**

charts display communication networks. Stakeholders in those networks are divided into three categories: Coffee Production Sector, Coffee Business Sector, and Government Sectors.

Category information is shown in the charts using both location and background color. The coffee production sector is shown in light brown, the coffee business sector is shown in light green and the government sector is given in light red. The New Coffee Federation and the PEARL Project exist at the intersection of two sectors, and are placed overlapping both sectors.

Current and desired communication patways are illustrated using a line from each network node to all the other network nodes where either a) current communication occurs or b) coffee farmers expressed a desired increase in communication. Current interaction is illustrated with thin black lines. A thick blue line shows desired new interactions between the local coffee co-op staff, farmers and the other stakeholders. A combination of a thick blue line with a co-linear thin black line indicates where improved communication is desired with current network stakeholders. The number of current interaction lines per stakeholder is scored by counting the thin black lines, and are given in the current interaction score for each stakeholder.

Due to the complexity and importance of maintaining the relationships between stakeholders in the Rwandan coffee industries an integrated chart was required to display all current and desired communication. The Rwandan Coffee Network Communication chart (see Figure 4) is a chart which incorporates multiple elements in the Rwandan coffee industry. Rather

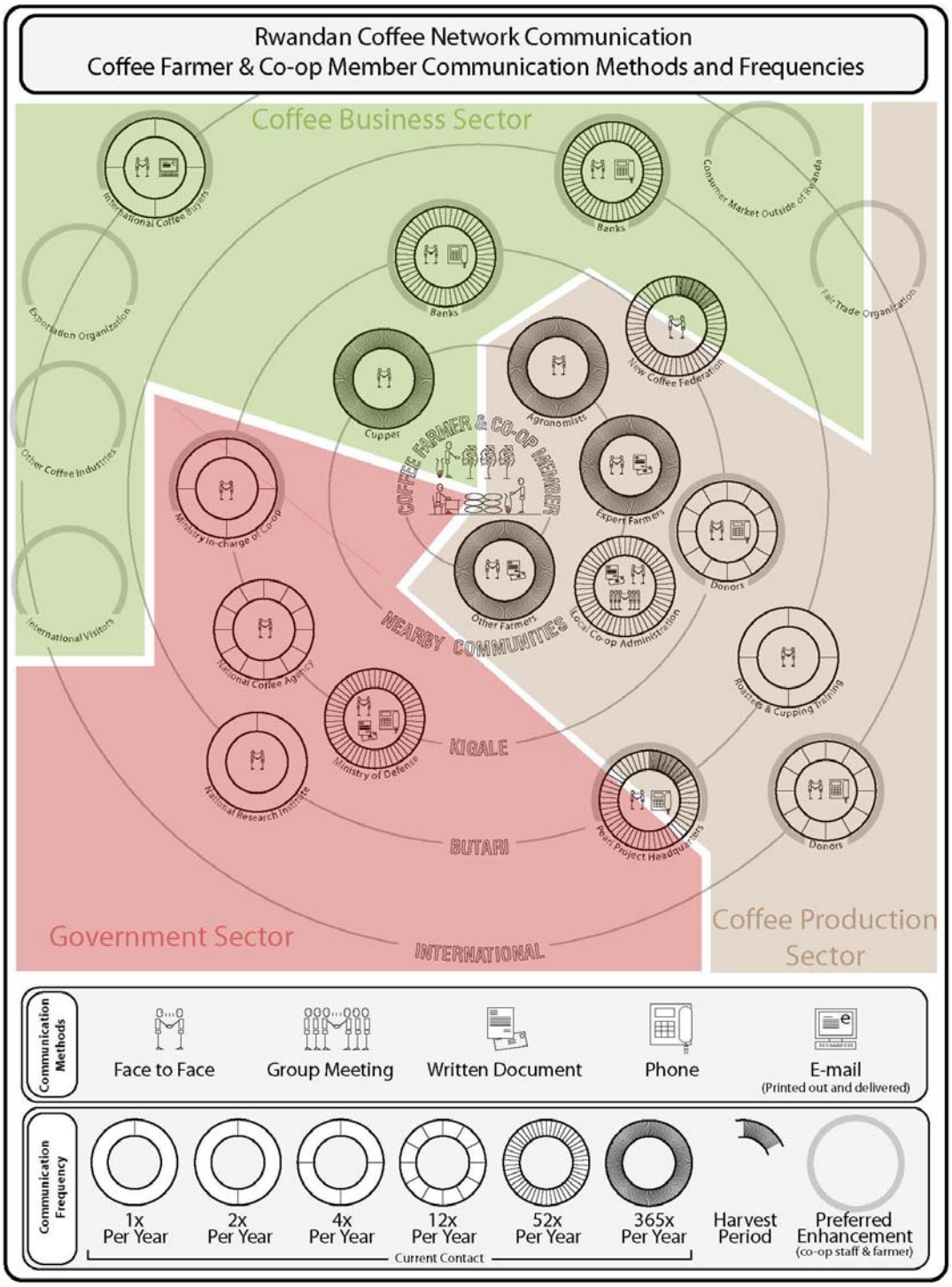

Figure 16. **Rwandan Coffee Farmer Communication Methods and Frequencies**

than displaying a series of individual charts, where each chart depicts a different subset of data which is disconnected from all others, we designed a new visual method of visual representation

which allows several data sets to be compressed into one chart. This method of visual representation allows a viewer to view multiple sets of data simultaneously so that a large variety of complex issues may be explored and integrated. In addition, these representations also effectively present key findings from a single set of data, which usually must be accomplished through the use of additional charts. To make more clear the full advantage of the integrated data represented in the charts, the following paragraphs also present a verbal explanation of the information contained in the charts.

The data sets that were used in Figure 4 were taken from six disconnected sets of data and then compiled into a single chart. These originally disparate sets were: stakeholder distances, communication frequency, communication method, current stakeholders, desired new and/or improved stakeholder connections, and sector category. The following list provides a detailed description of the primary data sets relating to the coffee farmer and Co-op member and interactions with each secondary stakeholder (i.e. Kigali banks, Rwanda Ministry of Defense, donors, etc):

- Sector Categories – This help describes what part the sector the stakeholder satellites may be involved with. The background colors on which the stakeholder satellites are resting indicate their sector. They may be a part of the business sector, government sector, or the sector of people or organizations involved with growing and processing the coffee. Some stakeholders may share roles in two sectors and they are shown overlapping both sector ground colors.
- Current Stakeholders Satellite – Represents the same stakeholders found in the interaction network charts. The current stakeholders are most critical to the Rwandan coffee industry. These are depicted as a thin solid black lined circle which includes the name of

the stakeholder, typical annual communication frequency, and current communication methods. The travel distance from the coffee farmer and co-op member is based on the location on which concentric distance circles (see also Travel Distance).

- Desired New or Improved Stakeholder Satellites – Data from when the farmer and co-op member have indicated a desire to establish a new contact or improved the contact with an existing stakeholder. A desired new stakeholder is represented by an independent blue halo with the new stakeholder title. This halo is placed on the satellite relative to the physical distance from the co-ops or farmers and in the correct sector category. No other data such as frequency or method is included. For the desired interaction improvement, a blue halo is placed around an existing satellite.
- Travel Distance – Distance is critical for current face to face and written documents distribution. The stakeholders are organized on satellites (concentric circles) radiating out from the Coffee Farmer & Co-op Member center circle. The distances have been broken down into the following categories: nearby communities, Kigale, Butari, and international with each category occupying its own orbit. Each concentric circle away from the center represents a relative distance that the communication must travel to reach the stakeholder. Although the circles are not spaced to scale they do represent the data as ordinal (closer in circles are closer to the farmers and further away distances are outer) in terms of distance between the coffee farmers and the stakeholder.
- Communication Methods – These communication methods are currently used to interact with the secondary stakeholder. Symbols representing the communication methodology used for each secondary stakeholder are located within each secondary stakeholder satellite.

- Communication Frequency – Communication frequency affects the time and energy spent by the primary stakeholder to maintain the critical interaction with the secondary stakeholders. Marks around the stakeholder satellites indicate the frequency of communication per year.

	Musasa		Karaba		Mugombwa		Nyakizu		Maraba	
	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
Gender *(n)*	13	4	3	6	8	5	4	5	8	5
Age										
mean	40.23	27.25	45.67	31.67	26.88	30.20	35.25	28.40	45.25	38.80
SD	12.09	3.78	14.57	12.94	4.05	12.91	12.84	4.40	11.65	12.48
Education										
None	1	0	0	0	0	0	0	0	0	1
Some	9	0	1	4	4	2	3	1	6	1
High School	3	4	1	2	4	3	1	4	2	3
Literacy[a]										
Non-readers	2	0	2	0	0	0	0	0	0	1
Intermediate	7	1	0	4	3	2	3	1	5	2
Advanced	4	4	0	2	5	3	1	4	3	2
Missing	0	0	1	0	0	0	0	0	0	0

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Evaluation of the current Rwandan coffee interaction network

chart and the current interaction score show that the most significant axis of interaction is with local coffee co-op staff.

Gender Differences

Overall, male co-op members were older than female co-op members, $t(59) = 2.25$, $p = .03$. This was the case statistically overall and numerically at all but the Mugombwa co-op (see Table 2). In addition, female co-op members were better educated than male co-op members, $\chi^2 (2, N = 61) = 6.70$, $p = .03$, with over 60% (see Table 3) having obtained a high school education.

Table 5. ***Demographics by Co-op and Gender***

[a] Non-readers were those who reported that they could not read, intermediate readers reported that they could read a limited set of materials including letters from acquaintances or periodicals, advanced readers reported that they could read books as well as periodicals and letters.

Table 6. ***Educational Attainment of Male and Female Co-op Members***

	Gender			
	Male		Female	
Education Level	**n**	**% of males**	**n**	**% of females**
No Formal Education	**1**	**2.8%**	**1**	**4%**
Some school	**23**	**63.9%**	**8**	**32%**
High School graduate	**11**	**30.6%**	**16**	**64%**
Missing	**1**	**2.8%**	**0**	**0%**

Familiarity

Because no participants were familiar with either a PDA or beeper, these two items were dropped from the rank analysis. In addition 2 participants did not provide rankings for all items both stating that they could not rank items they were unfamiliar with.

Overall communication method familiarity was determined by calculating the number of participants who selected each communication method card. As shown in Figure 6, all participants were familiar with face to face communication, most were familiar with letters, cell phones, desktop and laptop computers and faxes, but none were familiar with PDA's or beepers.

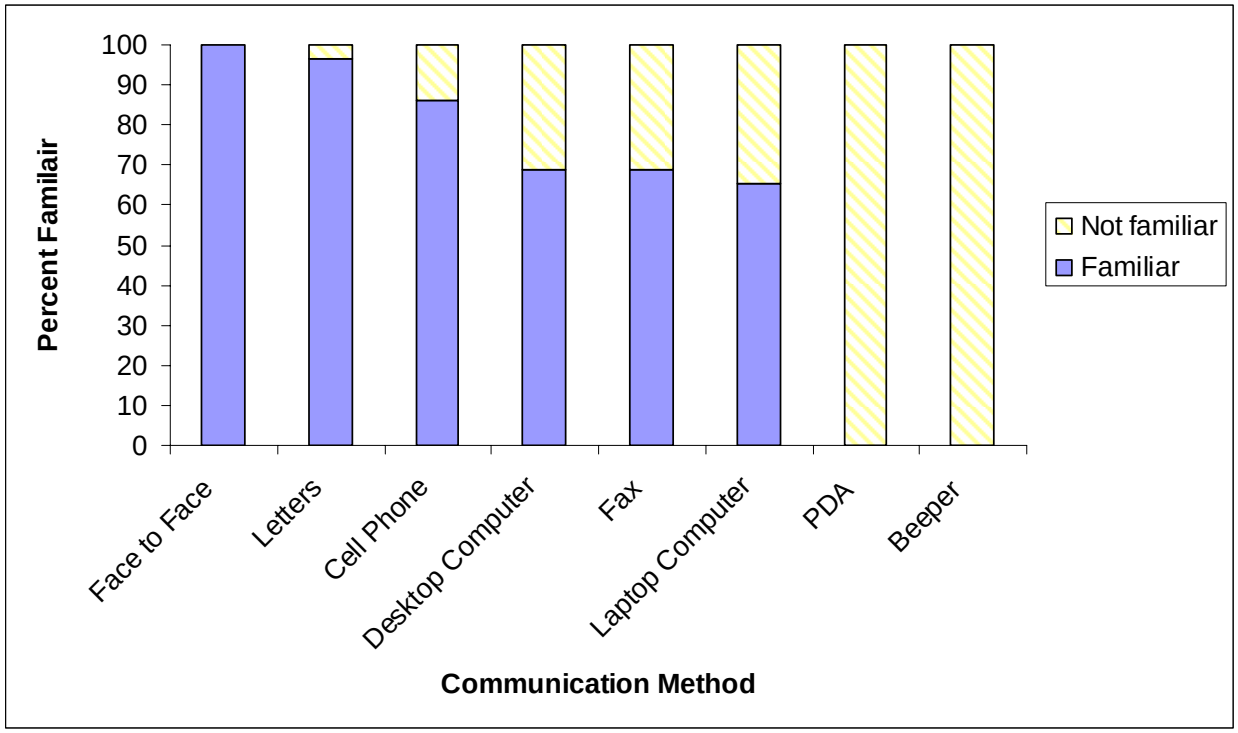

Figure 17. **Percentage of Farmers Familiar with Each Communication Method**

Gender was not significantly correlated with technology familiarity, $r(59) = .15$, $p = .45$ indicating that males and females had similar previous contact with these communications technologies. Age was negatively correlated with technology familiarity $r(59) = -.45$, $p = .02$ whereas education was positively correlated with technology familiarity $r(59) = .61$, $p < .001$

indicating that younger and more educated co-op members had more experience with communication technologies.

Communications Methods Rank

The mean rank for each communication method was calculated by summing the rank assigned to the method by each participant and dividing by the number of participants who ranked that method. Participants ranked "cell phones" the lowest (low numbers mean most desired, useful or easy to use) in both usefulness and desired future use, but ranked face to face communication as the easiest to use (see Figures 7, 8 & 9).

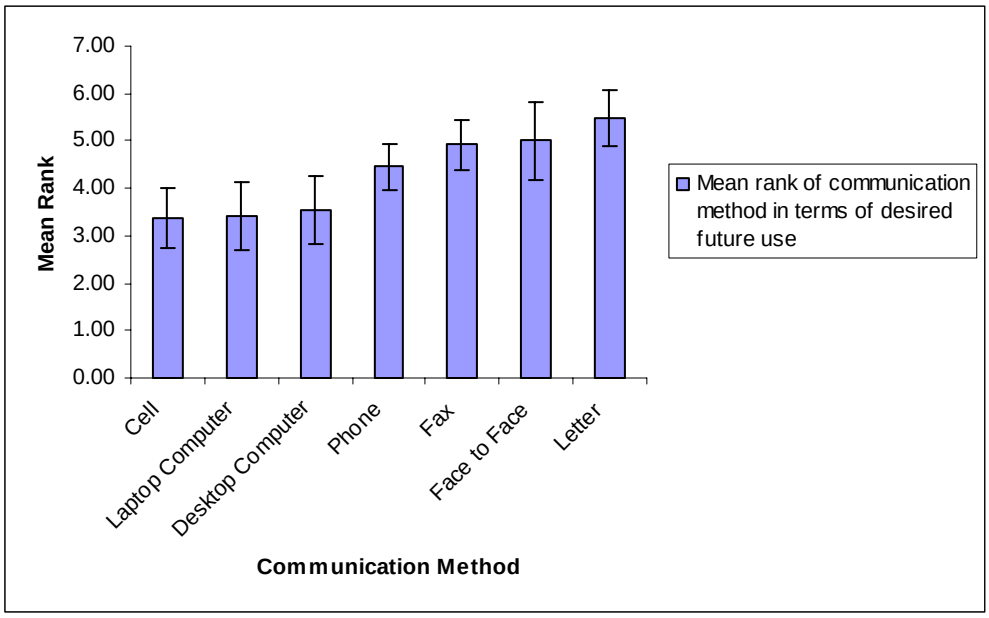

Figure 18. **Communication Methods Ranked in Order of Desired Future Use**

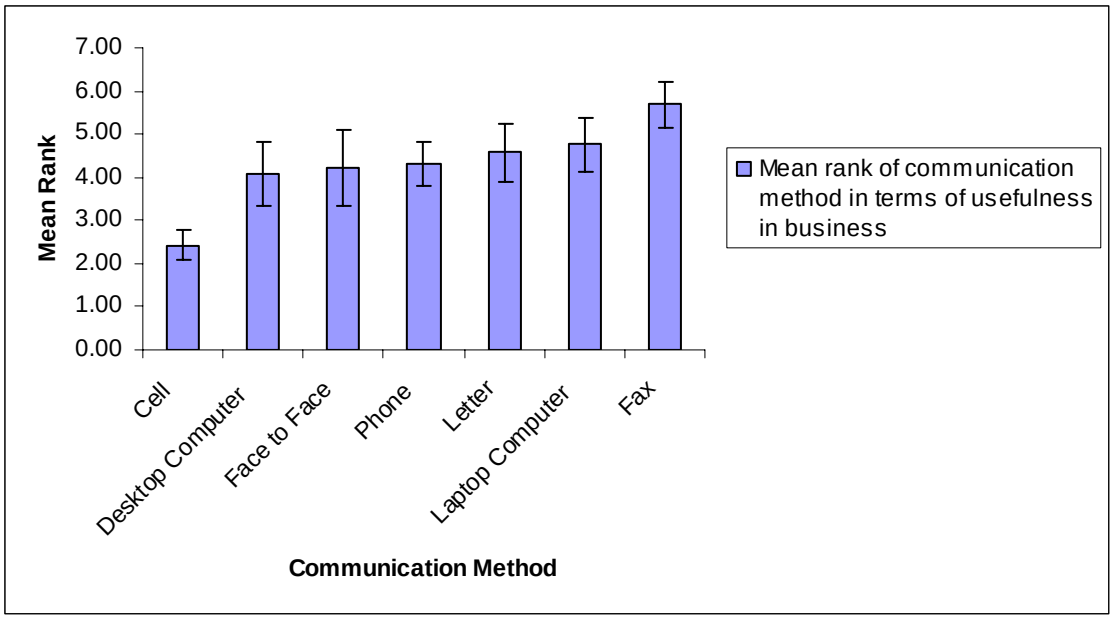

Figure 19. **Communication Methods Ranked in Order of Usefulness to Business**

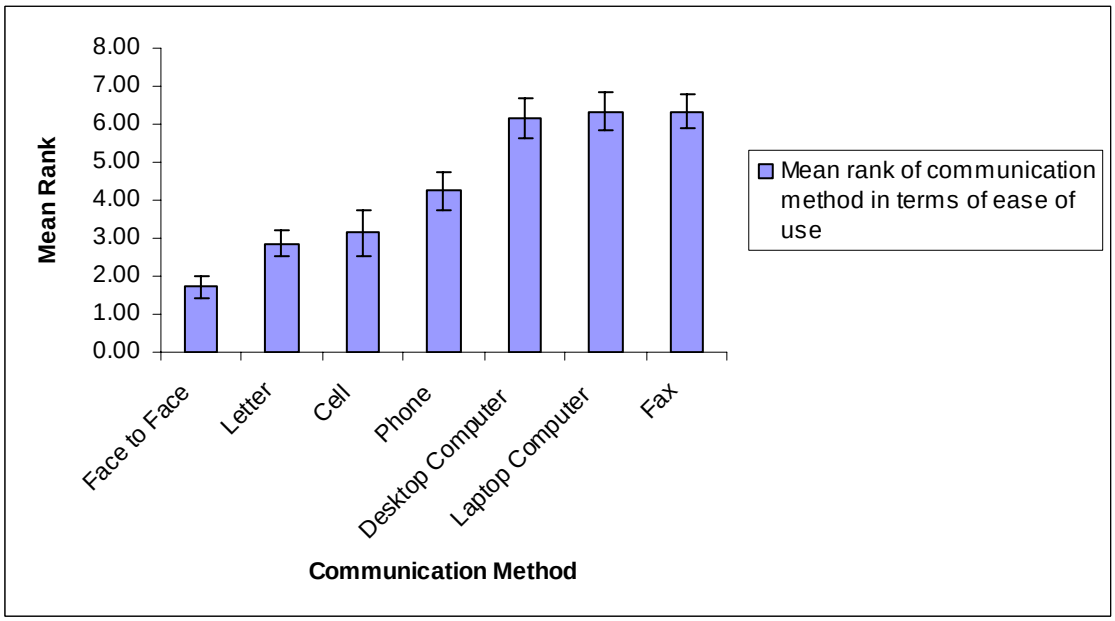

Figure 20. **Communication Methods Ranked Order of Ease of Use**

Discussion

The overall intent of this study was to inform our understanding of the information and communication needs of Rwandan coffee farmers. Specifically, the study examined the farmers' current communication situation and how the current situation could be improved. The study

also explored the technology familiarity and technology preferences among the farmers in hopes that a technology solution could be matched to this specific user group to improve the information and communication situation.

Overall the results indicate that a technology solution could improve the communication situation. The majority of participants were familiar with some ICT's and reported that they would like to use ICT's in the future. However, participants did rank non-technological solutions as easier to use than ICT's. Participants mentioned that although face to face communication is "easier to use" it's not always "easier." For instance many mentioned that in order for them to meet face to face with someone, often they had to walk for many hours. For example, we heard the following story recounted:

> After hours of travel the farmer or co-op member would finally reach an assembly point where they were expecting to meet face to face with another stakeholder. However, upon arrival, the farmer would come to find the person they were intending to meet was not there. While waiting for the other person to come, they would question to themselves, 'Are they not coming at all? Are they just a little bit late? Have they already been here waiting and have decided to return? Have they just stepped out for a quick bite to eat? Have they forgotten? Have I wasted my time walking all the way over here?'

This process could often take a whole day, with the possibility of a missed meeting quite real. However, problems such as this could be avoided if only stakeholders could communicate real time. After evaluating the frequency of these types of meetings, and considering the importance of maintaining the personal relationships between stakeholders future ICT's would be a remarkable and frequent benefit to all stakeholders.

In retrospect, to better evaluate with quantitative data it would have been better to have designed the question of ease of use with an additional location component. As it is, it seems that participants answered this question in terms of using the communication method with others who are co-located (where face to face communication is possible), rather than for communication with those who are a great distance away.

All desired communications mentioned in the interviews are in the coffee business sector. Both individual coffee farmers and expert farmers expressed the desire to have access to information directly from existing stakeholders. Currently, the co-op staff is fulfilling this role specifically in regard to relaying general agriculture, governmental, and business data to the farmers. However, much of the co-op staff's time and effort could be saved or better utilized if farmers had independent access to this type of specific information (especially personal banks accounts, a crop peculiarity found in their field, etc).

The appraisal of the preferred enhancement of new Rwandan coffee interaction networks showed a surprising interest of many of the stakeholders in the Coffee Producer Sector who are interested in improving connections with stakeholders in all three sectors.

An assessment of the relative distance in the Rwandan coffee network communication identified that the most desired future contacts are also the stakeholders at the greatest physical distance from the coffee farmer and co-op member. Most of the high frequency contacts are co-located or nearby other stakeholders. The banks, PEARL project headquarters, The Ministry of Defense, and the new coffee federation, because of the high frequency of communication, could benefit from the use of ICT's.

Limitations

Regrettably we did not collect data on the language(s) the participants spoke. However based on observation as well as a casual interview with our translator none of the participants we met with spoke fluent English, and in fact probably spoke only Kinyarwanda fluently, although some may have spoken some French. The language issue, although not explored in this study, may be a significant barrier to the successful use of ICT's in Rwanda. Others are attempting to overcome this barrier (Felix? Do we have a ref for his work on this?). Another possible addition to this study that would be useful would be the classification of interactions, in terms of which interactions require personal relationships to be maintained.

Conclusions

Most of the desired communication is with network nodes that are physically distant from the farmers. It is in just such situations where distance rather than desire prevent communication that ICT's can be of the most use. Our recommendation of type of device would be a cell phone because of participants ratings of cell phones as easy to use, useful in business and desire to use them in the future. In addition the language barriers mentioned in the limitation section may dissuade many farmers from using software that is not written in Kinyarwanda for communication.

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Appendix A

Demographics Questionnaire

Gender: Male 1 **Female** 2

Age: _____

1. What is your highest level of education?

1 No formal education
2 Less than high school graduate
3 High school graduate/GED
4 Vocational training
5 Some college/Associate's degree
6 Bachelor's degree (BA, BS)
7 Master's degree (or other post-graduate training)
8 Doctoral degree (PhD, MD, EdD, DDS, JD, etc.)

2. Please check all that apply.

1 I do not know how to read
2 I can street signs
3 I can read letters
4 I can read newspapers or magazines
5 I can read books
6 I enjoy reading

Appendix B

Current Communication Situation

The purpose of this set of questions is to assess your current communication situation.

1. Who do you *currently* communicate with about the coffee business?

(list in chart below)

2. How often do you communicate about the coffee business with each of the people you mentioned above (e.g., co-workers, roasters, Perl members, academics, etc.)?

(list in chart below)

3. What do you communicate about? (please list all things you discuss)

(list in chart below)

4. How do you communicate with this person (by what method - in person, via postal mail, phone, email, fax, internet chat)? (Ask for each person)

(list in chart below)

Who do you communicate with?	How often?	About what?	Method of communication?	What do you communicate about?

Who do you communicate with?	How often?	About what?	Method of communication?	What do you communicate about?

Ideal Communication Situation

The purpose of this set of questions is to assess the ideal communication situation.

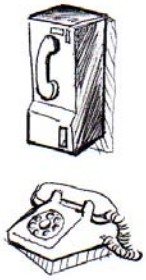
1. Who *would you like* to communicate with about the coffee business? (list in chart below)

2. What *would you like* to communicate about with this person? (list in chart below)

Who would you like to communicate with?	About what?

Appendix C

Pen & Paper

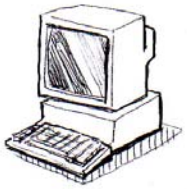


Telephone
(land line)

Fax

Pager

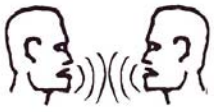
Cell Phone



Desk Top

Lap Top

PDA



Face to Face

Technology Experience Questionnaire

1. Please select the communication methods you are familiar with.

Appendix D

Technology Preferences Questions

1. Please rank these communication methods in terms of which you like to use in the future.
    a. Why?
2. Please rank the communication methods in terms of which you think would be most useful in the coffee business.
3. Please rank the communication methods in terms of which you think would be the easiest to use.

Pen & Paper | Telephone (land line) | Fax

Pager | Cell Phone | Desk Top

Lap Top | PDA | Face to Face

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